IDOE

ERNATIONAL DECADE OF OCEAN EXPLORATION

GRESS REPORT VOLUME 6: APRIL 1976 to APRIL 1977

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International Decade of Ocean Exploration, Progress Report: January 1970 to July 1972, published January 1973

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PROGRESS REPORT VOLUME 6

April 1976 to April 1977

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October 1977

Nations in IDOE

Argentina
Australia
Belgium
Bolivia
Brazil
Canada
Chile
China, Republic of
Colombia
Denmark
Ecuador
Fiji
France
Germany, Dem. Rep. of
Germany, Fed. Rep. of
Greece
Guatemala
Iceland
India
Indonesia
Israel
Italy
Jamaica
Japan
Khmer Republic
Korea, Republic of
Malaysia
Mexico
Morocco
Netherlands
New Zealand
Norway
Peru
Philippines
Portugal
Singapore
Spain
Sweden
Switzerland
Thailand
Tonga
Union of South Africa
United Kingdom
United States
USSR
Venezuela
Vietnam, Republic of

PREFACE

The International Decade of Ocean Exploration (IDOE) is a long-term, international, cooperative program to improve the use of the ocean and its resources for the benefit of mankind.

On March 8, 1968, the President of the United States proposed "an historic and unprecedented adventure—an International Decade of Ocean Exploration for the 1970's." In December 1968, the United Nations General Assembly endorsed "the concept of an international decade of ocean exploration to be undertaken within the framework of a long-term programme of research and exploration. . . ."

In late 1969, the Vice President of the United States, in his capacity as Chairman of the National Council on Marine Resources and Engineering Development, assigned responsibility for planning, managing, and funding the U.S. program to the National Science Foundation (NSF), and set forth the following goals:

- Preserve the ocean environment by accelerating scientific observations of the natural state of the ocean and its interactions with the coastal margin—to provide a basis for (a) assessing and predicting man-induced and natural modifications of the character of the oceans, (b) identifying damaging or irreversible effects of waste disposal at sea, and (c) comprehending the interaction of various levels of marine life to permit steps to prevent depletion or extinction of valuable species as a result of man's activities;

- Improve environmental forecasting to help reduce hazards to life and property and permit more efficient use of marine resources—by improving physical and mathematical models of the ocean and atmosphere to provide the basis for increased accuracy, timeliness, and geographic precision of environmental forecasts;

- Expand seabed assessment activities to permit better management—domestically and internationally—of marine mineral exploration and exploitation by acquiring needed knowledge of seabed topography, structure, physical and dynamic properties, and resource potential, and to assist industry in planning more detailed investigations;

- Develop an ocean monitoring system to facilitate prediction of oceanographic and atmospheric conditions—through design and development of oceanographic data buoys and other remote sensing platforms;

• Improve worldwide data exchange through modernizing and standardizing national and international marine data collection, processing, and distribution; and

• Accelerate Decade planning to increase opportunities for international sharing of responsibilities and costs for ocean exploration, and to assure better use of limited exploration capabilities.

Shortly after receiving the Vice-President's charge, the National Science Foundation set up the Office for the International Decade of Ocean Exploration and began to define the United States program. In the first year of IDOE's existence, three areas were chosen for priority attention: (1) environmental quality; (2) environmental forecasting; and (3) seabed assessment. In 1971, living resources was added as a fourth program area.

A key goal of IDOE has been to make sure that data from all projects will be available to future users. In pursuit of this objective, the IDOE Office of NSF contracted with the Environmental Data Service (EDS) of the National Oceanic and Atmospheric Administration to manage the scientific data for IDOE. The agreement included publishing this series of reports.

Feenan D. Jennings, Head
Office for the International
Decade of Ocean Exploration

INTRODUCTION

This report, the sixth in a series, provides the scientific community and other interested persons with information, data inventories, and lists of scientific reports derived from U.S. IDOE projects. The text is arranged according to the program areas established for IDOE. Details of subprograms are given under appropriate programs. Currently funded projects are listed. Bibliographies follow subprogram text.

Appendix A contains the Report of Observations Samples Collected by Oceanographic Programs (ROSCOP), a summary of reported observations received during the period covered by this Report. All IDOE grant holders must submit ROSCOP reporting forms to NOAA Environmental Data Service's National Oceanographic Data Center (NODC) upon completion of a data collection activity. The ROSCOP summaries in Appendix A follow the same program sequence as the text.

Two charts follow the appendices. The first shows ocean areas for which data and ROSCOP summaries have been received by NOAA's Environmental Data Service (EDS) during the period covered by this report. The second shows ocean areas for which data have been received by EDS from January 1970 to April 1977. Each numbered area is about 1,100 by 1,100 km (600 by 600 nmi) and, although entirely shaded, may contain only one reported observation.

EDS either has the data, track charts, or papers described in this report in one of its center archives or knows where they may be obtained. Queries may be addressed to any of the following EDS centers:

National Oceanographic Data Center (NODC)
National Oceanic and Atmospheric Administration
Washington, DC 20235
Tel: (202) 634-7234
IDOE Project Leader: S. O. Marcus, Jr.

Marine Geology and Geophysics Branch
National Geophysical and Solar-Terrestrial Data Center (NGSDC)
National Oceanic and Atmospheric Administration
Boulder, CO 80302
Tel: (303) 499-1000, ext. 6339
IDOE Project Leader: J. B. Grant

Environmental Science Information Center (ESIC)
National Oceanic and Atmospheric Administration
Washington, DC 20235
Tel: (202) 634-7399
IDOE Project Leader: R. R. Freeman

National Climatic Center (NCC)
National Oceanic and Atmospheric Administration
Federal Building
Asheville, NC 28801
Tel: (704) 258-2850, ext. 765
IDOE Project Leader: R. Quayle

CONTENTS

HIGHLIGHTS OF PAST YEAR'S PROGRAM

The unseasonably cold winter of 1976 and 1977 in the Eastern United States and the near-drought conditions in the Midwest during the summer of 1976 and on the west coast during the winter of 1977 have increased our awareness of the role of weather and climate in our lives. IDOE programs continue to advance our understanding of weather and climatic changes.

In the North Pacific Experiment (NORPAX), scientists have continued their efforts to link large areas of unusually warm or cold sea-surface waters in the North Pacific to seasonal weather patterns over the United States. One aspect of these studies involved efforts made by Jerome Namias of the Scripps Institution of Oceanography to forecast these patterns 3 months in advance. In spring 1976, he correctly predicted the warm, dry weather in the North Central States and the cool, wet weather in the Pacific Northwest during that summer. These forecasts suggest that the oceans play a pivotal role in shaping seasonal weather patterns, and that the ability to predict these patterns will depend on the extent to which researchers can refine their understanding of air-sea interactions.

On a much longer-term basis, scientists in the Climate, Long-range Investigation, Mapping, and Prediction (CLIMAP) program have used fossils captured in deep-sea sediment cores to describe the main features of the global environment 18,000 years ago. Drawing on this data, they found that changes in the distribution of solar radiation caused by changes in the path of the Earth's orbit, its tilt, and wobble are the fundamental causes of the waxing and waning ot ice ages during the last 500,000 years. Although these changes are relatively small, they produce major climatic changes. Ignoring the possible effect of man-made influences, the data indicate a coming, extensive glaciation period for the Northern Hemisphere over the next few thousand years.

To document the theory that changes in the Earth's orbit cause global climatic changes, CLIMAP scientists studied variations in the geochemistry and abundance of microorganisms preserved in deep-sea cores. These data were analyzed statistically to determine their dominant cycles in the core. The results showed that these are cycles of 21,000 years, 42,000 years, and 100,000 years—the same as the cycles of variations in the Earth's tilt, wobble, and path around the sun.

There were several major field operations during the past year. The Coastal Upwelling Ecosystems Analysis (CUEA) program, a major international effort to understand the forces driving the highly productive coastal upwelling areas, mounted its sixth and final field experiment, JOINT-II, in spring 1977. JOINT-II investigations were carried out in an area about 100 by 100 km off the coast of Peru, between Pisco and San Juan. During the final phase, observations were made from seven U.S. and Peruvian research vessels, aircraft, moored current meters, coastal meteorological stations, and satellites. The results will be given in next year's report.

Also in early 1977, scientists supported by the Seabed Assessment Program used the submersible ALVIN to dive over 3,000 m below the surface of the Pacific Ocean to explore and sample eruptions of superheated, metal-rich water from the sea floor. They worked in a portion of the Galapagos Rift, 350 km northeast of the Galapagos Islands and 800 km west of Ecuador. The area is on an ocean spreading center or boundary between two sections, or plates, of the Earth's crust. Molten materials flow up from the interior of the Earth through the cracks between the plates, forming new crust and forcing additional sea-floor spreading—and sometimes earthquakes. Data from the dives promise to shed some light on the way in which metal-rich,

deep-sea sediments are formed, the chemical history of seawater, and the transfer of heat from the Earth's interior into the oceans.

Two programs, the Geochemical Ocean Sections Study (GEOSECS) and the Manganese Nodule program, assumed new directions during the past year. In late 1977, GEOSECS will embark on its final phase in the Indian Ocean. Scientific techniques that were developed and applied to analysis of data collected during the Atlantic and Pacific phases have resulted in a large data base. An eight volume set of atlases displaying the data is now under preparation.

The Manganese Nodule program entered a new phase of research in early 1977. Begun in 1972, the initial stages were successful in providing an inventory of the existing knowledge and data related to manganese nodules. As a result of that work, a series of maps were prepared showing worldwide distribution of nodules and their chemical composition. The second phase of the program began in 1974 and was designed to initiate field work in the central Pacific. Detailed surveys, nodule sampling, and chemical analyses were done during this phase. The program has determined the mineralogy of ferromanganese minerals in the nodules as well as the crystallographic locations of the economically important transition elements. Work on the age of nodules has shown that introduction of young material along cracks in nodules can produce spurious growth rate data. During 1975, first-generation bottom ocean monitors were deployed in the central Pacific. Current meters, nephelometers, and time-lapse cameras operated for 120 days on the monitors. Photographs showed high biological activity on the sea floor around manganese nodules.

The program is now using bottom ocean monitors for geochemical studies on how the chemical composition of nodules relates to (1) the fluxes of transition metals at a range of nodule sites, (2) the chemistry of the solutions in which nodules grow, and (3) the reactions between nodule-forming ferromanganese minerals and enclosing pore waters and bottom waters.

A Marine Science Affairs program was set up within IDOE to provide a link between scientific findings and their social, economic, and political implications. It will provide research support for a small number of projects in two broad areas: (1) to analyze the implications of new knowledge generated by IDOE scientific programs for public policy; and (2) to improve the conduct and management of IDOE scientific programs. Guidelines for requesting project grants are available from the NSF IDOE office, Washington, D.C. 20550.

A major effort during the past year was devoted to designing a program to succeed the current IDOE, which ends in 1980. This effort reflects the recommendations of the National Advisory Committee on Oceans and Atmosphere (NACOA) in its midterm review of the IDOE, an ad hoc panel from the National Academies of Science and Engineering, and the IDOE Advisory Panel.

During spring 1977, the University of Rhode Island's Center for Ocean Management Studies sponsored five workshops to consolidate the ideas of the oceanographic community for the post-1980 program. Each workshop involved about 20 specialists in physical, chemical, biological, and geological oceanography. Letters inviting ideas were also sent to participants in these disciplines and to professional journals.

The National Academies of Science and Engineering have assisted the IDOE Office in these activities through the appropriate groups within the Academies, including the Ocean Sciences Board, the Marine Board, and the Ocean Policy Committee. NAS/NAE also organized a major workshop for September 1977 to consolidate and synthesize ideas from the earlier letters and workshops into a framework for an oceanographic research program for the 1980's. The results of these efforts will be described in next year's "Progress Report."

Sampling a small bag for zooplankton using a bongo net

Environmental Quality Program

This program is designed to provide information on the quality of the oceanic environment and to assess and predict man's impact on this environment through research in geochemical processes and marine pollution. The present program consists of four major investigations: the Geochemical Ocean Sections Study (GEOSECS), which is concerned with detailed measurement of physical and chemical characteristics of ocean waters along Arctic to Antarctic sections; the Pollutant Transfer Program, which involves investigations of mechanisms and pathways by which pollutants are transported to and within the oceans; the Biological Effects Program, which assesses the impact of selected pollutants on marine organisms; and the controlled Ecosystem Pollution Experiment (CEPEX), which is providing information about the effects of pollutants on pelagic communities contained in large plastic enclosures.

Geochemical Ocean Sections (GEOSECS) Study

GEOSECS is an international cooperative program involving geochemists from 14 United States universities. Investigators from Belgium, Canada, France, Germany, India, Japan, and the United Kingdom are also participating in GEOSECS or are carrying out similar programs coordinated by the United States. The U.S. program involved the occupation of 121 oceanographic stations in the Atlantic and 147 stations in the Pacific. These stations were located along north-south survey tracks and generally coincided with the paths of bottom-water currents. Samples of water and suspended materials collected at these stations and selected depths are being analyzed for approximately 40 physical and chemical parameters, including temperature, salinity, pH, alkalinity, P_{CO_2}, dissolved and trace gases, nutrients, trace metals, dissolved and particulate organic and inorganic matter, natural radionuclides, manmade radionuclides, and stable isotopes.

The data are being used to determine the stirring and reaction processes in the deep sea, the interchange of material between deep and surface waters, and the exchange of water and gases with the atmosphere. The data provide a baseline for measuring amounts of pollutants, specifically nuclear and waste products, that are being introduced into the ocean. Projects in this program are listed in table 1.

GEOSECS scientists have found that radioactive chemical tracers can provide information about large-scale ocean mixing patterns and rates of water movement. One of the manmade radionuclides, tritium, was released in Arctic waters and is being tracked by the scientists in bottom water formed in this part of the world (fig. 1). To a lesser extent, added radiocarbon follows a similar distribution pattern, but this material shows predominant accumulation in the midlatitudes (fig. 2).

By measuring a short-lived natural radioactive component of dissolved matter in seawater, like Ra^{228} and Rn^{222}, GEOSECS scientists have derived K_v, the eddy diffusivity (fig, 3). K_v measures the rate at which dissolved material is transported across a concentration gradient. When the density structure (measured as a buoyancy gradient) of different water masses was plotted against K_v, a trend was obtained (fig. 3) that can be used for predicting the mixing properties of any water mass once its density structure is known.

GEOSECS scientists have developed vertical transport models based on evidence that fecal pellets from zooplankters and small fish, along with clays, appear to scavenge from seawater soluble constituents, such as heavy metals. Although more data are required to properly test the models for the scavenging process, statistical use of these models in deep water has demonstrated significant differences in the particle-assisted settling rates for copper, antimony, and scandium as compared with nickel, for which no scavenging is indicated.

In the western basin of the Atlantic Ocean, GEOSECS scientists have identified three major water types by their concentration of dissolved oxygen and dissolved nitrate. Bacterial decomposition of organic matter in the ocean results in a decrease in dissolved oxygen and a simultaneous increase in dissolved nitrate. Almost all of this organic matter can be simulated by a simple five-to-six carbon amino acid, requiring nine molecules of oxygen to completely oxidize the molecule to CO_2, N_2O_5, and H_2O. Because the loss of nine molecules of oxygen from the water always results in a gain of an atom of nitrogen during respiration (or the reverse process for photosynthesis), the quantity $[O_2 + 9\ NO^-_3]$ is conserved during these biological changes.

GEOSECS Data

The GEOSECS operation group at the Scripps Institution of Oceanography (SIO) has established a central data processing facility. This facility is presently producing special data reports for GEOSECS investigators and preparing a final data report of shipboard analysis and several detailed chemical oceanographic atlases. Laboratories have completed some analyses and have forwarded these data to SIO (table 2). Analyses of the remaining Atlantic and Pacific samples are being completed.

Table 1.—U.S. institutions, investigators, and projects in GEOSECS program

Institutions	Investigators	Projects
University of California, San Diego, Scripps Institution of Oceanography	A. E. Bainbridge and H. Craig	Operations Group and SIO Shipboard and Laboratory Measurements
	C. D. Keeling	Precision Measurements of Carbon Dioxide
The City University of New York, Queens College	T. Takahashi	Carbonate Chemistry of Seawater
Columbia University, Lamont-Doherty Geological Observatory	W. S. Broecker, P. E. Biscaye, and Y. H. Li	The Analysis of GEOSECS Samples Collected in the Atlantic, Pacific and Indian Oceans for Ra-228, Th-228, and Suspended Particulates
University of Hawaii	P. Kroopnick	Isotopic Measurements
Louisiana State University	L. M. Chan and J. S. Hanor	Barium Analyses in Ocean Waters
Massachusetts Institute of Technology	J. M. Edmond	High-Precision Barium, Copper, Nickel, and Cadmium measurements
University of Miami, Rosenstiel School of Marine and Atmospheric Science	H. G. Östlund	Radiocarbon and Tritium Measurements
University of South Carolina	W. S. Moore	Measurement of Ra^{228} in Seawater
University of Southern California	T. L. Ku	Radium Analysis
University of Washington	M. Stuiver	C^{14} Ocean Water Analysis
Woods Hole Oceanographic Institution	D. W. Spencer	Administrative and Logistic Activities
	P. G. Brewer	Particulate Matter in the Atlantic and Pacific Oceans
Yale University	K. K. Turekian	Strontium and Lead Analysis
	M. E. Fiadeiro	Three-Dimensional Modeling of Tracers in the Ocean

A water library is maintained at WHOI. Samples are preserved in plastic containers for subsequent use by any investigator with a suitable scientific project. Limited amounts of samples also are stored in glass ampoules for analyses of dissolved gases. *Earth and Planetary Science Letters* (Vol 32, 1976) has devoted an entire issue to GEOSECS papers on results from 1973–76.

GEOSECS Bibliography

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Alvarez-Borrego, S., C. H. Culberson, and P. K. Park. 1975. Oxygen-nutrient relationships in the Pacific Ocean. Limn. & Oc. 20:806–814.

Bacon, M. P., D. W. Spencer, and P. G. Brewer. 1976. $^{210}Pb/^{226}Ra$ and $^{210}Po/^{210}Pb$ disequilibria in seawater and suspended particulate matter. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):277–296.

Biscaye, P. E., V. Kolla, and K. K. Turekian. 1976. Distribution of calcium carbonate in surface sediments of the Atlantic Ocean. J. Geophys. Res. 81:2595–2603.

Boyle, E., and J. M. Edmond. 1975. Copper in surface waters south of New Zealand. Nature 253:107–109.

Brewer, P. G., and J. C. Goldman. 1976. Alkalinity changes generated by phytoplankton growth. Limn. & Oc. 21:108–117.

Brewer, P. G., D. W. Spencer, P. E. Biscaye, A. Hanley, P. L. Sachs, C. L. Smith, S. Kadar, and J. Fredericks. 1976. The distribution of particulate matter in the Atlantic Ocean. Earth and Planet Sci. Lett 32 (GEOSECS Collected Papers: 1973–1976):393–402.

Broecker, W. S., J. Goddard, and J. Sarmiento. 1976. The distribution of ^{226}Ra in the Atlantic Ocean. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976): 220–235.

Brown, R. A., and H. L. Huffman, Jr. 1976. Hydrocarbons in open-ocean waters. Sci. 191:847–749.

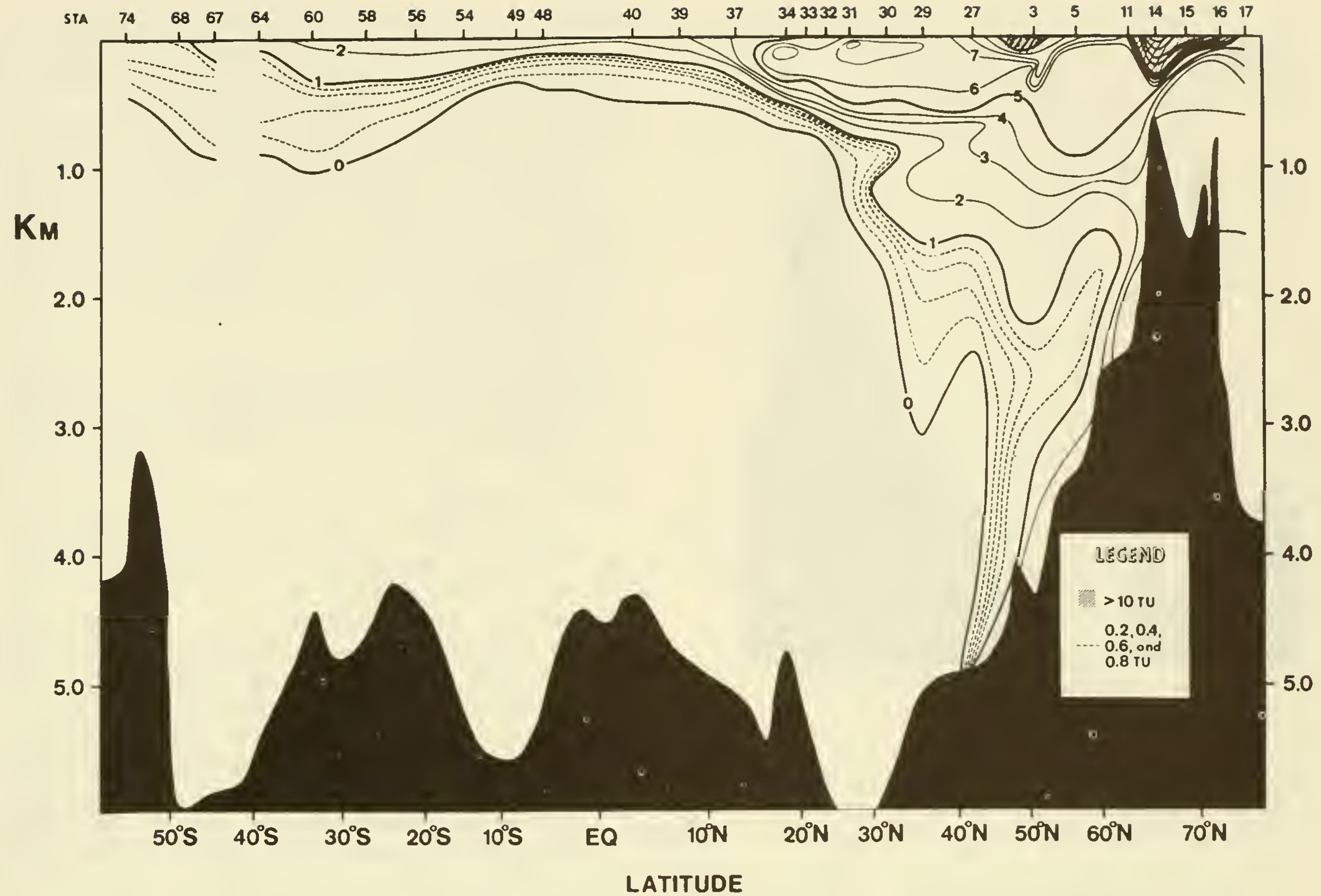

Figure 1.—Tritium in the Western Atlantic, 1972–73 (in tritium units, T atoms per total H).

Chan, L. H., J. M. Edmond, R. F. Stallard, W. S. Broecker, Y. C. Chung, R. F. Weiss, and T. L. Ku. 1976. Radium and barium at GEOSECS stations in the Atlantic and Pacific. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):258–267.

Chung, Y. C. 1976. A deep ^{226}Ra maximum in the northeast Pacific. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):249–257.

Craig, H., and K. K. Turekian. 1976. The GEOSECS program: 1973–1976. Earth and Planet. Sci. Lett. 32 (GEO SECS Collected Papers: 1973–1976):217–219.

Dorsy, H. G., and W. H. Peterson. 1976. Tritium in the Arctic Ocean and East Greenland Current. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976): 342–350.

Harrison, C. G. A., and E. Ramirez. 1975. Areal coverage of spurious reversals of the earth's magnetic field. J. Geomag. Geoelectr. 27:139–151.

Krishnaswami, S., D. Lal, and B. L. K. Somayajulu. 1976. Investigations of gram quantities of Atlantic and Pacific surface particulates. Earth and Planet. Sci. Lett. 32 (GEO SECS Collected Papers: 1973–1976):403–419.

Krishnaswami, S., D. Lal, B. L. K. Somayajulu, R. F. Weiss, and H. Craig. 1976. Large-volume in situ filtration of deep Pacific waters: Mineralogical and radioisotope studies. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):420–429.

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Kroopnick, P., and H. Craig. 1976. Oxygen isotope fractionation in dissolved oxygen in the deep sea. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):375–388.

Kroopnick, P. M. 1975. Respiration, photosynthesis, and oxygen isotope fractionation in oceanic surface water. Limn. & Oc. 20:988–992.

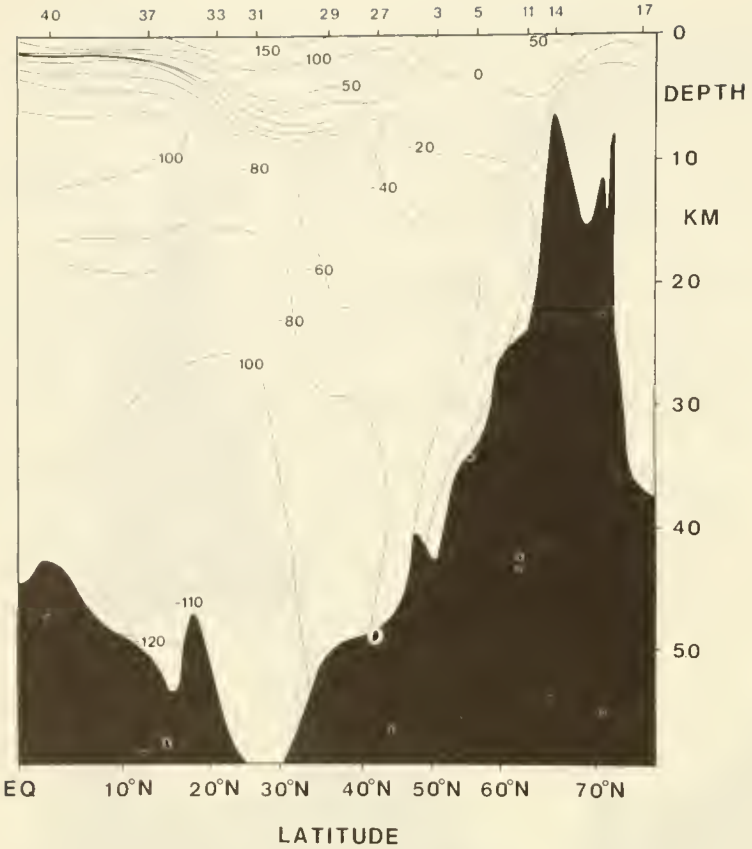

Figure 2.—Radiocarbon in the Northwestern Atlantic, 1972–73 (in thousandths of total carbon).

Table 2.—Laboratories conducting trace element and radioactive constituent analyses for GEOSECS

Battelle Laboratories—Northwest, Richland, Wash.
Centre National de la Recherche Scientifique de Faibles Radioactive, Gif-sur-Yvette, France
University of Hawaii, Honolulu, Hawaii
Lamont-Doherty Geological Observatory, Palisades, N.Y.
Louisiana State University, Baton Rouge, La.
McMaster University, Hamilton, Ontario, Canada
Physical Research Laboratory, Ahmedabad, India
Scripps Institution of Oceanography, La Jolla, Calif.
University of Southern California, Los Angeles, Calif.
University of Washington, Seattle, Wash.
Woods Hole Oceanographic Institution, Woods Hole, Mass.
Yale University, New Haven, Conn.

Ku, T. L., and M. C. Lin. 1976. ^{226}Ra distribution in the Antarctic Ocean. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):236–248.

Longinelli, A., M. Bartelloni, and G. Cortecci. 1976. The isotopic cycle of oceanic phosphate, I. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976): 389–392.

Lupton, J. E. 1976. The ^{3}He distribution in deep water over the Mid-Atlantic Ridge. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):371–374.

Millero, F. J., A. Gonzalez, P. G. Brewer, and A. Bradshaw. 1976. The density of North Atlantic and North Pacific deep waters. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):468–472.

Nozaki, Y., J. Thompson, and K. K. Turekian. 1976. The distribution of ^{210}Pb and ^{210}Po in the surface waters of the Pacific Ocean. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):304–312.

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Park, P. K., L. I. Gordon, and S. Alvarez-Borrego. 1974. The carbon dioxide system of the Bering Sea. In: Oceanography of the Bering Sea (D. W. Hood and E. J. Kelley, eds.) Chap. 5, Inst. Mar. Sci., Univ. of Alaska, p. 107–147.

Ribbat, B., W. Roether, and K. O. Munnich. 1976. Turnover of Eastern Caribbean deep water from ^{14}C measurements. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):331–341.

Sarmiento, J. L., D. E. Hammond, and W. S. Broecker. 1976. The calculation of the statistical counting error for ^{222}Rn scintillation counting. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):351–356.

Sarmiento, J. L., H. W. Feely, W. S. Moore, A. E. Bainbridge, and W. S. Broecker. 1976. The relationship between vertical eddy diffusion and buoyancy gradient in the deep sea. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):357–370.

Sclater, F. R., E. Boyle, and J. M. Edmond. 1976. On the marine geochemistry of nickel. Earth and Planet. Sci. Lett. 31:119–128.

Somayajulu, B. L. K., and H. Craig. 1976. Particulate and soluble ^{210}Pb activities in the deep sea. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976): 268–276.

Spencer, D. W., and A. Bainbridge. 1971. GEOSECS: A program for the International Decade of Ocean Exploration. Mar. Tech. Soc. 5:23–26.

Stuiver, M. 1976. The ^{14}C distribution in west Atlantic abyssal waters. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):322–330.

Takahashi, T., M. O. Weaver, and L. A. Prince. 1976. The effect of oxygen in the carrier gas for infrared gas analysis of CO_2. J. Geophys. Res. 81:3736–3738.

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Thompson, J., and K. K. Turekian. 1976. ^{210}Po and ^{210}Pb distributions in ocean water profiles from the eastern South Pacific. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers: 1973–1976):297–303.

Tomlinson, R. D., and L. I. Gordon. 1973. A sample changer

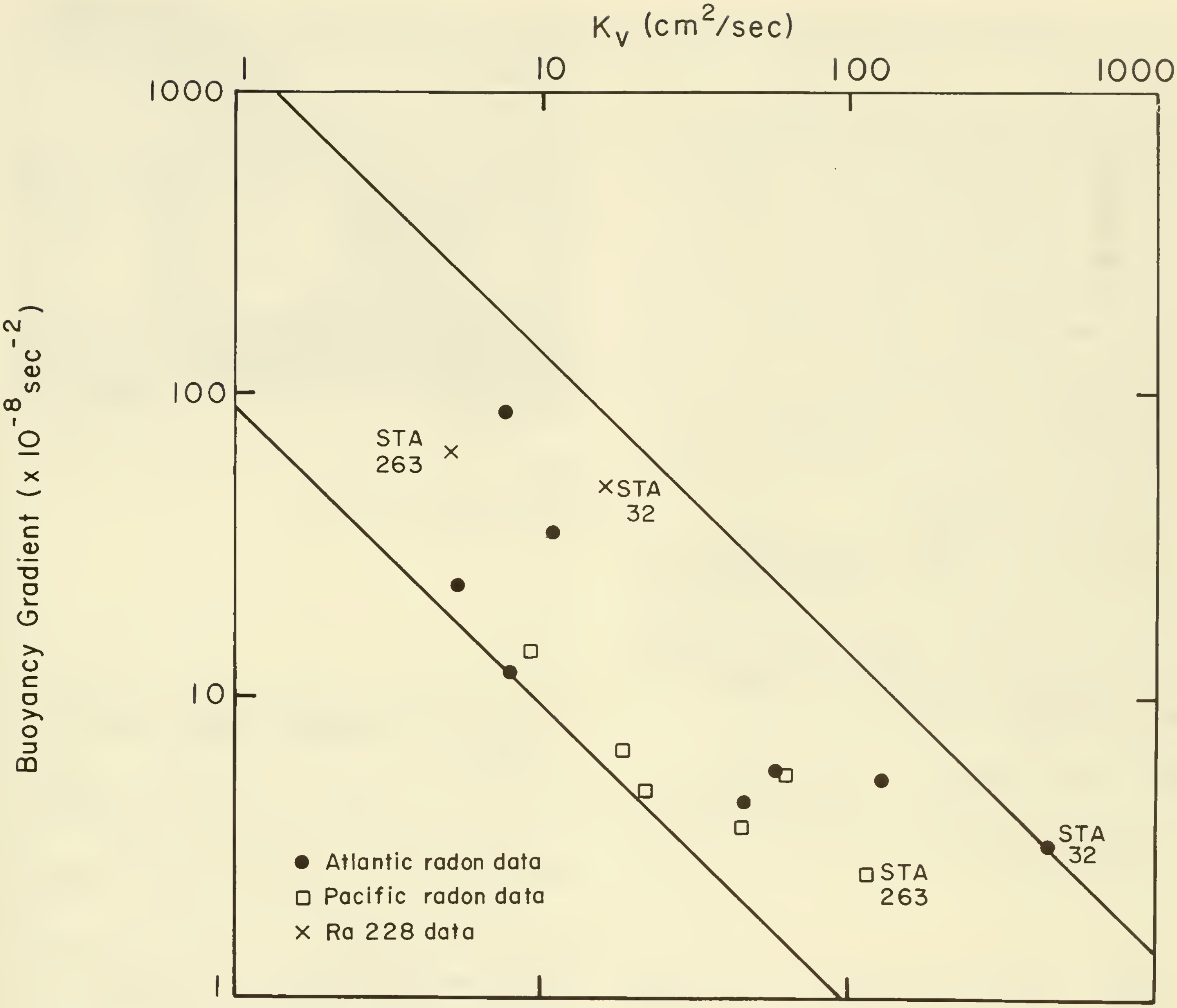

Figure 3.—Density structure vs. eddy diffusivity.

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Wong, G. T. F., P. G. Brewer, and D. W. Spencer. 1976. The distribution of particulate iodine in the Atlantic Ocean. Earth and Planet. Sci. Lett. 32 (GEOSECS Collected Papers):441–450.

Pollutant Transfer Program

In the Pollutant Transfer Program, initiated in 1972, processes that transfer pollutants from land sources to the oceans and movement and concentration of these pollutants in the oceans are being investigated. Objectives are to: (1) identify important transfer pathways and mechanisms, (2) evaluate major environmental factors that influence transfer processes, and (3) develop principles governing the transfer of pollutants. Of special interest are the concentration and dispersal of pollutants at the air-sea interface, movement of pollutants through estuaries to continental shelf waters, deposition of pollutants in sediments, and the chemical form and degradation of these pollutants in the marine environment.

The atmosphere is a major route of transfer for chlorinated and petroleum hydrocarbons and trace metals. Results of studies on atmospheric transfer of trace metals suggest that, except for sea salts, most airborne trace metals over the open ocean and Antarctica are from normal weathering of the earth's crust. However, the concentrations of several easily vaporized trace metals (antimony, cadmium, copper, lead, selenium, and zinc) are greater than those predicted to be of crustal origin.

A highly significant relation was found between cadmium and phosphate in coastal Pacific waters (fig. 4). The correlation indicates that cadmium is taken up by phytoplankton along with nutrients. The possibility of this mechanism taking

place was strengthened by the finding of higher cadmium concentrations in deep waters where mineralization of organic matter takes place.

In addition to the well-publicized distribution of PCB (polychlorinated biphenyls) and DDT (dichlorodiphenyl-trichloroethane), the presence of PAE's (phthalate ester plasticizers) in the aquatic environment has been determined and found to be widely dispersed. Concentrations of the phthalates are typically 10-fold higher than that for both PCB and DDT.

Atmospheric samples in the Samoa area were analyzed for iron as an indicator of continental dust. Iron concentrations here were less than those found both near Hawaii and Bermuda, in accord with their proximity to terrestrial sources. Trace metals such as As, Cd, Cu, Hg, Pb, Sb, Se, and Zn are associated with the fine fraction ($d \leq 0.25$ppm) of air-borne particulate matter that is known to have the longest residence time in the atmosphere. Over half of air-borne organic carbon is also associated with these fine particles, so that important studies are underway to determine their source. The projects in this program are listed in table 3.

In July 1976, seven IDOE-funded scientists conducted an intercalibration cruise to sample water, sediment, atmosphere, plankton, and surface microlayer for both natural and synthetic hydrocarbons. These samples will be used to measure chlorinated hydrocarbon concentrations (PCB and DDT) in the sea.

The proceedings from a workshop at Skidaway Institute of Oceanography, January 1976, have been published in the book *Marine Pollutant Transfer.*

Launching "MAC" from deck of RV KNORR. *Air samples collected over the sea by "MAC" are analyzed for light, volatile, halogenated hydrocarbons*

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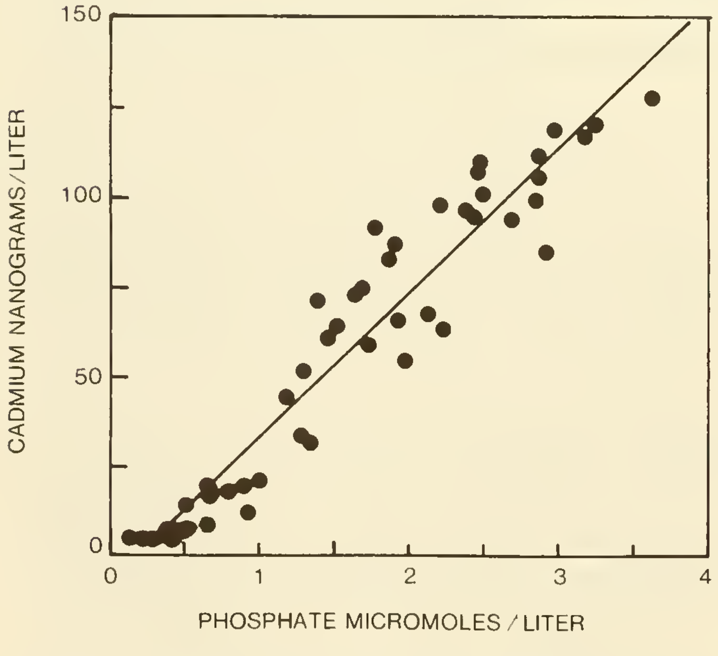

Figure 4.—Relation between cadmium and phosphate in coastal Pacific waters.

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Table 3.—U.S. institutions, investigators, and projects in Pollutant Transfer Program

Institutions	Investigators	Projects
California Institute of Technology	C. C. Patterson	Determination of Input and Transport of Pollutant Lead in Marine Environments Using Isotope Tracers
University of California, Bodega Marine Laboratory	R. Risebrough	Fluxes of Organochlorine Pollutant Through the Marine Environment
University of California, Scripps Institution of Oceanography	E. Goldberg	Low Temperature Volatilization of Heavy Metals from Crustal Rocks
University of Georgia, Skidaway Institute of Oceanography	H. L. Windom	The Transfer of Heavy Metals Through the Inner Continental Shelf to the Open Ocean
Harvard University, Bermuda Biological Station, Inc.	J. N. Butler and B. F. Morris	Transfer of Petroleum Residues in Sargasum Communities and the Water of the Sargasso Sea
University of Rhode Island	R. A. Duce	Anomalously Enriched Elements in the Marine Atmosphere: Sources, Distribution, and Fluxes
	C. E. Olney and T. F. Bidleman	Atmospheric Transport and Deposition of High Molecular Weight Chlorinated Hydrocarbons on the Ocean Surface
San Jose State University	J. H. Martin	Cadmium Transport to the Open Pacific Ocean Via the California Current
Texas A & M University	C. S. Giam	Phthalate and Chlorinated Hydrocarbon Transfer Processes in the Marine Environment
Woods Hole Oceanographic Institution	G. R. Harvey	A Detailed Inventory of Concentration-Fluxes of the Major Halogenated Pollutants at 2 Sites in the Northwest Atlantic

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Biological Effects Program

Investigators in the Biological Effects Program are conducting laboratory studies to evaluate the sublethal, low-level effects of trace metals, petroleum, chlorinated hydrocarbons, and phthalates on the behavior and biochemical processes of individual classes of organisms. The objectives of this program are to determine which species, life cycle stages, and physiological processes are most affected by various types of pollutants, and at what levels. In addition, the investigators are looking specifically for biological indicators that can be used as early warning systems to detect pollutant-induced perturbations in the open ocean. The projects in this program are listed in table 4.

Several pollutants are acutely toxic in the parts-per-million range to bacteria, phytoplankton, zooplankton, and higher marine organisms. Generally, heavy metals (mercury and copper) and chlorinated hydrocarbons (e.g. PCB-Aroclor 1254) are found to be more toxic than petroleum hydrocarbons. And phthalates, which are more abundant than PCB's or DDT, appear to be less toxic to higher organisms.

Results of some studies indicate that concentrations of 80 ppb Aroclor 1016 and 100 ppb Halowax 1099 were acutely toxic to the larvae of the mud crab (*Rhithopanopeus harrissi*), while Halowax 1000 at 300 ppb was chronically toxic. Sublethal responses showed developmental abnormalities including increased development time to megalops, decreased megalops size, and an increased number of zoeal stages.

In experiments studying the effects of water soluble fractions (WSF) of No. 2 fuel oil on crab larvae, it was found that after 2 days, the survival of stone crab zoea was reduced at a concentration of 4% (6 ppm). Mortality increased with concentration and duration of exposure, and after 3 days, all larvae in a 20% (3 ppm) solution were dead.

Aqueous extracts of No. 2 fuel oil retarded or arrested development of barnacle eggs at 3 ppm, while acute experiments with sea urchin gametes, embryos, and larvae, as well as larvae of several crab species showed that a concentration of 0.6 ppm was deleterious to development and survival. Of the oils tested (aqueous extracts), Bunker C and No. 2 fuel oil were more toxic than Alaska and Southern Louisiana Crude.

Results from studies of the uptake of radio-labeled hydrocarbons added to food or water of blue crabs (*Callinectes sapidus*) indicate that the metabolism and discharge of hexadecane, naphthalene, and methylnaphthalene were more rapid than that of fluorene, benz(a)pyrene, and methylcholanthrene. Uptake from both food and water resulted in most of the radioactivity eventually building up in the hepatopancreas with only minor amounts of hydrocarbons in gonad or muscle tissue.

Copper concentration of 500 ppb for 130 days were acutely toxic to both megalops and juvenile stages of *Callinectes similis*. Chronic toxicity was detected at 250 ppb. Crab mortalities caused by exposure to lethal concentrations of copper usually occurred during or immediately after molt.

Three new research projects were started this year to focus more specifically on biological indicators that could be used to detect pollutant-induced perturbations in the ocean. One will investigate the ability of low levels of petroleum hydrocarbons to induce mixed function oxidaces in fish species from three different environments. Another will use light microscopes and an electron microscope to determine the condition of respiratory, digestive, and reproductive tissue in marine organisms that have been exposed to petroleum hydrocarbons. The incidence of infection and tumor formation will be measured and compared with physiological parameters being measured by others doing comparable experiments. Investigators will attempt to quantify the effects of chemical gradients (copper ions and PCB's) and water flow rates on the locomotor and orientation behavior of certain fishes.

A Biological Effects workshop was held in May 1976 at Texas A&M University. The proceedings for this meeting are currently in press. In October 1976, a workshop, Anoxia On the Middle Atlantic Shelf During the Summer of 1976, was held in Washington, D.C. This report is available from the Office for the IDOE, NSF, Wash., D.C. 20550.

Table 4.—U.S. institutions, investigators, and projects in Biological Effects Program

Institutions	Investigators	Projects
University of Alaska	P. B. Reichardt and D. K. Button	Lability of Aromatic Hydrocarbons and Their Nonlethal Effects on Marine Organisms
University of California, Scripps Institution of Oceanography	G. N. Somero and T. J. Chow	The Effects of Lead and Cadmium on Selected Developmental, Physiological and Biochemical Processes in Marine Animals
University of Delaware	M. R. Tripp	Histopathology of Benthic Invertebrates
Florida State University	J. A. Calder	Investigations of Breakdown and Sublethal Biological Effects in Trace Petroleum Constituents in the Marine Environment
University of Georgia, Skidaway Institute of Oceanography	R. F. Lee	Fate of Petroleum Hydrocarbons in Marine Food Web
Texas A & M University	J. M. Neff	Sublethal Effects of Selected Heavy Metals and Organic Compounds on Organisms From the Gulf of Mexico
	C. S. Giam	Biological Effect of Phthalates and Chlorinated Hydrocarbons in Biota from the Gulf of Mexico
	W. M. Sackett	Fate, Spatial, and Temporal Distribution of Petroleum-Derived Organic Compounds in the Ocean, and their Sublethal Effects on Marine Organisms
	H. Kleerekoper	Subacute Effects of PCB's and Copper Ions in Locomotor and Orientation Behavior in Certain Marine Fishes
University of Texas, Marine Science Institute	J. A. C. Nichol and C. Van Baalen	Marine Petroleum Pollution: Biological Effects and Chemical Characterization
Woods Hole Oceanographic Institution	J. J. Stegeman	Xenobiotic (Hydrocarbon) Metabolism by Mixed Function Oxidases in Estuarine, Coastal, and Open Ocean Fish Species

Controlled Ecosystem Pollution Experiment (CEPEX)

CEPEX is an international, cooperative, field research project that involves trapping water and natural pelagic marine communities in large plastic enclosures (10 m diameter by 23 m deep) and assessing the effects of selected pollutants on these ecosystems. The field site is located in Saanich Inlet, Vancouver Island, British Columbia. The projects in this program are listed in table 5.

Generally, all pollutants introduced to the experimental containers to date show similar first effects on the organisms present. Specifically, the effects of metals and petroleum on bacteria are transient and short-term owing to the population's rapid adaptation (about 3 days) to imposed stress. Consequently, measurements of heterotrophic activity are probably not reliable as potential indicators of pollutant stress after the first few days of exposure.

Phytoplankton also adapt to stress quickly (less than 15 days). In mixed populations of bacteria and phytoplankton, measures of standing crop (chlorophyll, ATP, carbon) and rate functions (carbon-14 and nutrient uptake kinetics, etc.) provide little information on the effects of pollutants at the ecosystem level.

Some physiological measurements (respiration, excretion rates) show little relation to pollution stress in zooplankton. Other indices of metabolic well-being (egg production, feeding rate) are sensitive indicators of stress at sublethal levels. In general, small zooplankton, regardless of species, are more sensitive than larger organisms (except jellyfish). The consequences of pollution on higher trophic levels, for the most part, remain unsolved.

The Mercury III experiment was run in the large bags for 71 days during summer 1976. On day 9, mercury was added to the two experimental bags at concentrations of 1 and 5 parts-per-billion (ppb). On three occasions (day 24, 37 and 52), water and sediment were pumped from the bottom of the bags to reseed the surface layer. Nutrients were also added on day 37 and 52. During the experiment, the 1 ppb and control bags showed a close replication in dominance and abundance of phytoplankton and zooplankton species. The centrate diatoms, initially captured in all three bags, were almost gone before addition of the mercury. They were replaced by flagellates and dinoflagellates after the first and second upwelling and silicoflagellates after the third upwelling. A wide variety of zooplankton species was captured initially. The copepod populations showed no decline and reached 40,000 to 50,000/m^3. The plankton predators were low in number in all bags.

Large CEPEX bags in Saanich Inlet

Table 5.—U.S. institutions, investigators, and projects in Controlled Ecosystem Pollution Experiment

Institutions	Investigators	Projects
University of Alaska, Marine Science Institute	J. J. Goering and A. Hattori	Nitrogen and Silicon Regeneration in Controlled Aquatic Ecosystems
University of California at San Diego, Institute of Marine Resources	J. R. Beers	The Role of Microzooplankton in an Environmental Effects Program
	R. W. Eppley	Kinetics of Nutrient Assimilation by Phytoplankton
	W. H. Thomas	Effects of Pollutants on Marine Phytoplankton
	F. Azam	Role of Bacteria in Polluted Marine Ecosystems
University of Georgia, Skidaway Institute of Oceanography	D. W. Menzel	Integrated Field Studies and Operations
	H. L. Windom	Heavy Metal Variations in Natural and Polluted Ecosystems
University of Miami, Rosenstiel School of Marine and Atmospheric Science	M. R. Reeve	The Role of Zooplankton in an Environmental Effects Program
Woods Hole Oceanographic Institution	G. W. Grice	Zooplankton Population Assessment

Seining for fingerling salmon in large CEPEX bags

In the 5 ppb bag, dinoflagellates predominated after the first upwelling. The second upwelling stimulated an increase in centrate diatoms, not seen in the other two bags. It is possible that after the initial decimation of copepods and the subsequent recovery of small copepods in this bag, there was a lack of grazing pressure on the diatoms.

The Hydrocarbon III experiment, also run during summer 1976, involved the addition of aromatic hydrocarbons (naphthalene, 1-methylnaphthalene, 2,3-dimethylnaphthalene, and deuterated benz(a)anthracene) in a small bag experiment.

The results showed that diatoms declined rapidly during the first 2 weeks in both the control and treated bag, and were rapidly replaced by a dominant dinoflagellate (*Gyrodinium* spp.). Although there were significant enhancements in the basic photosynthesis-related metabolism of the phytoplankton, there were no significant effects on total phytoplankton biomass other than those of grazing pressure and sinking rates. Possibly, the concentration of naphthalene was not high enough to produce significant stimulation of large chain forming diatoms.

The large bag experiments show that pollutant effects may not necessarily be detected unless they are catastrophic. Also, the results obtained are specific to a particular geographic area and the organisms which occur in that area. They cannot be generalized for all environments. Finally, results can be altered by manipulating either end of the food chain, i.e., by stressing with pollutants at the lower level or removing predators at the higher level.

Efforts are being made to separate the effects caused by changes in grazing pressure and predatory stress on grazers. At present, the effects of pollutants on benthic organisms are not being investigated in the CEPEX program.

The spring 1977 issue of the *Bulletin of Marine Science* is devoted entirely to CEPEX papers.

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Environmental Forecasting Program

The Environmental Forecasting Program focuses on projects designed to explain the large-scale, long-term behavior of the ocean and the ocean's influence on weather and climate. Experiments and studies include: the Joint U.S.-U.S.S.R. Mid-Ocean Dynamics Experiment (POLYMODE); the North Pacific Experiment (NORPAX); the International Southern Ocean Studies (ISOS); and the Climate: Long-Range Investigation, Mapping, and Prediction (CLIMAP) Study.

MODE

Joint U.S.-U.S.S.R. Mid-Ocean Dynamics Experiment (POLYMODE)

The purpose of POLYMODE is to establish the dynamics and statistics of mesoscale motions in the ocean, their energy source, and their role in the general circulation of the ocean. POLYMODE is based on: 1) the U.S.S.R. Polygon project—a continuing series of experiments investigating mesoscale phenomena in the Atlantic and Pacific Oceans and in the Arabian Sea, and 2) the Mid-Ocean Dynamics Experiment (MODE project) of the United States and the United Kingdom. The POLYMODE experiment is under the direction of a Joint U.S.-U.S.S.R. POLYMODE Organizing Committee, established under the Agreement between the Governments of the United States and the U.S.S.R. on Cooperation in Studies of the World Ocean. Other countries have been invited to participate in POLYMODE by the UNESCO/International Oceanographic Commission's Scientific Committee on Oceanographic Research (SCOR) Working Group 34.

The overall description of the U.S. POLYMODE effort is described in *IDOE Progress Report Volume 5*. After a series of feasibility experiments in fall and winter 1976, the U.S.S.R. recommended that the location of the Northern Synoptic Experiment be moved to 29°N, 70°W to coincide geographically with the Southern Synoptic Experiment. There is now only one POLYMODE Local Dynamics Experiment. This report describes U.S. POLYMODE deep-current measurements, joint U.S.-U.S.S.R. activities, and the Local Dynamics Experiment. U.S. POLYMODE statistical-geographical experiments (Array 3, XBT sections) and theoretical and numerical studies are not described in this report.

U.S. participation in POLYMODE is sponsored jointly by the IDOE Office and the Office of Naval Research. Projects in POLYMODE are listed in table 6.

Deep-Current Measurements

The purpose of U.S. POLYMODE Arrays 1 and 2 was to extend the study of low-frequency fluctuations from the MODE-1 site to the east along 28°N and to the north along 55°W to other regions of the subtropical gyre. The location of these arrays is shown in figure 5. Array 1 measurements took place from July 1974 to April 1975. Array 2 measurements span the 27-month period from March 1975 to June 1977.

Also shown in figure 5 are volume transport streamlines for the deep (potential temperature less than 4°C) general circulation of the North Atlantic as deduced by Worthington from hydrographic measurements. The shape of this subtropical gyre is concentrated more north and north-westward and is smaller than previously suggested. A medium-scale gyre west of the Mid-Atlantic Ridge transports about 30 Sverdrups (Sv) through the Straits of Florida. A smaller gyre, which transports about 120 Sv, is embedded in the northern and western corner of the larger gyre. The smaller scale gyre contains all of the so-called downstream increase in transport of the Gulf Stream and all of the deep, general circulation of the entire subtropical gyre. A controversial element of this circulation pattern as drawn by Worthington is that approximate geostropic balance is violated in the westward return flow east of the Gulf Stream.

Current meter measurements have found the deep, easterly flow associated with the Gulf Stream to be comparable in magnitude (5 to 10 cm s^{-1}) to that suggested by Worthington, although displaced 100 to 200 km to the south in moored data (fig. 6A). A deep, westward mean flow north of and under the Gulf Stream, stronger and broader than implied by Worthington, is characteristic of the moored current meter data. In the offshore return flow near 4,000 m depth, westerly velocity components are about three times as large as assigned by Worthington, and the width of the return flow is three times smaller.

Figure 6B presents estimates of low-frequency ("eddy") kinetic energy for deep currents (4,000 m) for two sections across the subtropical gyre at 55°W and 70°W. The eddy kinetic energy distribution at each longitude has nearly the same characteristic shape. Peak values of the eddy kinetic energy occur about 200 km south of the Gulf Stream axis and decrease to the north and south. The properties of the eddy field vary with position by about two orders of magnitude and appear to be associated with properties of the general circulation as well as the bottom topography. The intensity and spatial variability of the eddy field is in sharp contrast to that of higher frequency (one cycle per hour to one cycle per day). For example, along 55°W near 4,000 m depth between 28° and 41.5°N, the kinetic energy of the higher frequency band varies between 2 and 6.5 cm^2s^{-2}, whereas the low-frequency kinetic energy varies from less than 1 to 162 cm^2s^{-2}.

Table 6.—U.S. institutions, investigators, and projects in POLYMODE

Institutions	Investigators	Projects
University of California, San Diego	R. Salmon and M. C. Hendershott	Statistical Properties of Quasi-Geostrophic Ocean Flow Models
Harvard University	A. R. Robinson	Analytical and Numerical Studies of Mesoscale Motions
Massachusetts Institute of Technology	C. Frankignoul and H. Stommel	Mesoscale Forcing of the Upper Layer of the Ocean
	R. Heinmiller H. Stommel	Coordination, Planning, Workshops, Communications, and Administration
	V. Lee and H. Stommel	MODE-I Atlas
	C. Wunsch	Moored Arrays for Study of Low-Frequency Oceanic Variability
U.S. Naval Academy	L. Dantzler	An Evaluation of Mesoscale Oceanic Eddy Statistics From Both Historical and Ship-of-Opportunity XBT Data
Naval Research Laboratory	J. Dugan	POLYMODE Synoptic Surveys
Nova University	P. Bedard	A Moored Array for Study of Low-Frequency Oceanic Variability in the Atlantic North Equatorial Current (Array 3, Cluster C)
Oregon State University	P. Niiler	A Moored Array for Study of Low-Frequency Oceanic Variability in the Atlantic North Equatorial Current (Array 3, Cluster C)
University of Rhode Island	H. T. Rossby	A Synoptic Study of Barotropic and Baroclinic Eddies in the Ocean
	R. Watts	A Study of Small-Scale, High-Frequency Displacements of the Main Thermocline in the Region of the Western Sargasso Sea
University of Washington	B. Taft, J. C. McWilliams and C. Ebbesmeyer	Hydrography Program for the Local Dynamics Experiment
Woods Hole Oceanographic Institution	N. P. Fofonoff	Moored Arrays for Study of Low-Frequency Oceanic Variability in the Region of the Mid-Atlantic Ridge (Array 3, Clusters A and B)
	N. P. Fofonoff and W. J. Schmitz	An Intercomparison of U.S. and U.S.S.R. Moorings, Current Meters, and Conductivity-Temperature-Depth Instruments
	J. Luyten	Moored Current Measurements for the Local Dynamics Experiment
	G. Metcalf	A Coordinated Expendable Bathythermograph (XBT) Program
	T. Sanford	A Study of the Vertical Structure and Energy of Midocean Eddies Using Electromagnetic and Doppler Profilers
	D. C. Webb	Float Project
	F. Webster	Newsletter
Yale University	R. Hall	Nonlinear Effects on the Scattering of Quasi-Geostrophic Waves

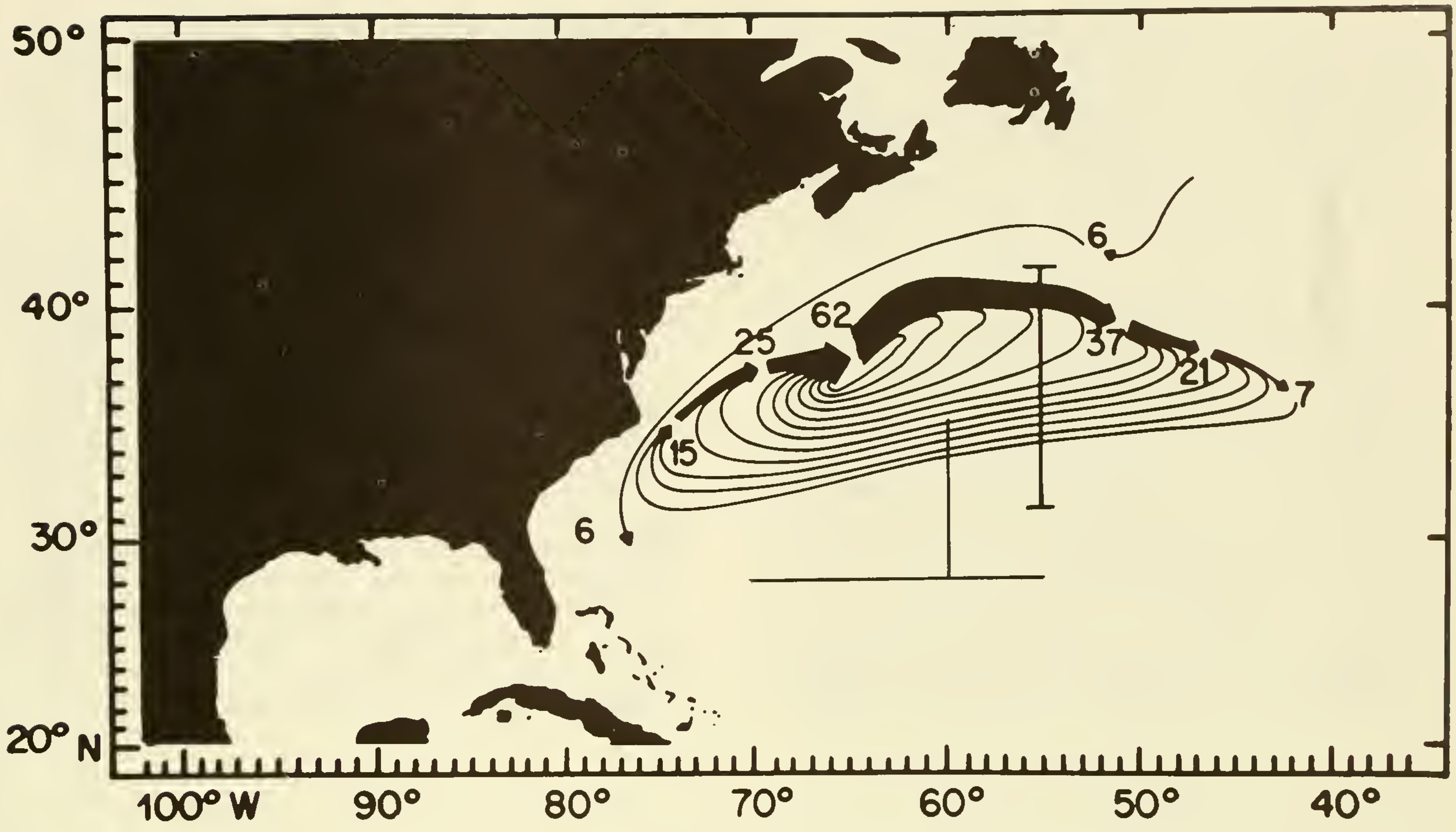


Figure 5.—Volume transport streamlines for the deep (potential temperature less than 4°C) general circulation of the North Atlantic according to Worthington. Numbers indicate transport in Sverdrups The locations of Array 1 (along 28°N. and 60°W) and Array 2 (along 55°W) are indicated by straight lines.

The distributions of momentum flux (off-diagonal component of the horizontal Reynolds stress tensor) in figure 6C indicate that the dynamics of the mean flow may be significantly influenced by the structure of the deep-eddy field. The momentum transport by the eddy field is neglected relative to the momentum transport by the mean flow in inertial models of the Gulf Stream or of the subtropical gyre. Taking one term as an indicator of the potential relevance of this assumption, the latitudinal derivatives of $\overline{u'v'}$ and $\overline{u}\,\overline{v}$ are of the same order for the 4,000 m data along 55° W. In frictional models, the momentum transport by the mean flow is neglected relative to the momentum transport by the fluctuations, and a constant positive eddy viscosity is used. Again looking at one term as an example, the ratio (eddy viscosity) of $-u'v'$ to the latitudinal derivative of the zonal mean flow is both positive and negative, and varies by an order of magnitude for the data along 55°W. This ratio is negative in the region of eastward mean flow to the offshore side of the axis of the Gulf Stream and in the westward return flow. The corresponding term (the negative product of u and the latitudinal derivative of $u'v'$) in the energy budget for the mean flow, based on 4,000 m data at 55°W, is the largest (and from low-frequency fluctuations to the mean flow) in the regions of eastward mean flow offshore of the axis of the Gulf Stream and in the westward return flow to the south.

Recent gyre-scale numerical models capable of resolving eddies yield a deep-mean circulation driven by the eddies. This class of models and the data described above are qualitatively similar in some respects; detailed quantitative comparisons await more thorough analysis, a more substantial data base, and more realistic models. Nevertheless, it seems possible that the directly wind-driven segment of the North Atlantic subtropical gyre is confined to about 30 Sv moving through the Straits of Florida, with a sizeable fraction of the downstream increase (120 Sv according to Worthington) in transport of the Gulf Stream system induced by the spatial inhomogeneity in the eddy field, especially at depths below the main thermocline.

Joint U.S.-U.S.S.R. Activities

Work with the Soviet Union has consisted of planning meetings, theoretical and experimental discussions, and joint cruises to intercompare instruments. Three specific results of this activity are:

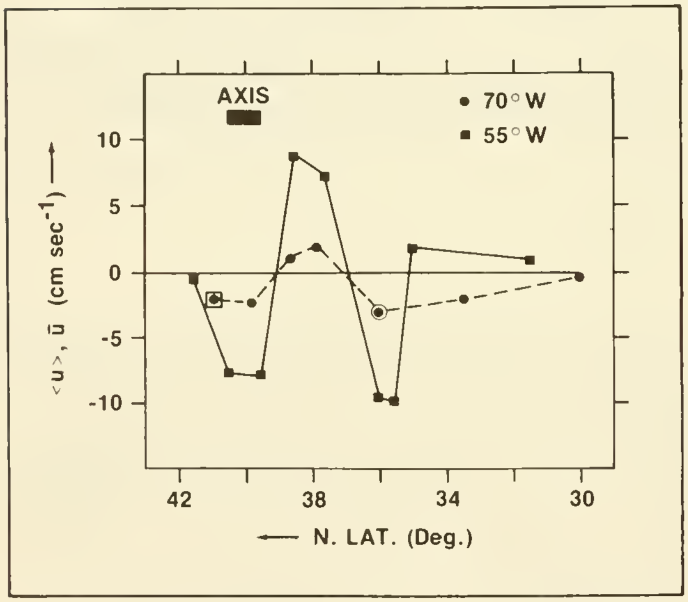
1. POLYMODE Joint Summer Theoretical Institute. A 3-week meeting of theoreticians and computer modelers was held in Yalta, U.S.S.R., in August 1976. The meeting brought together scientists actively involved in the POLYMODE experimental program with those newly

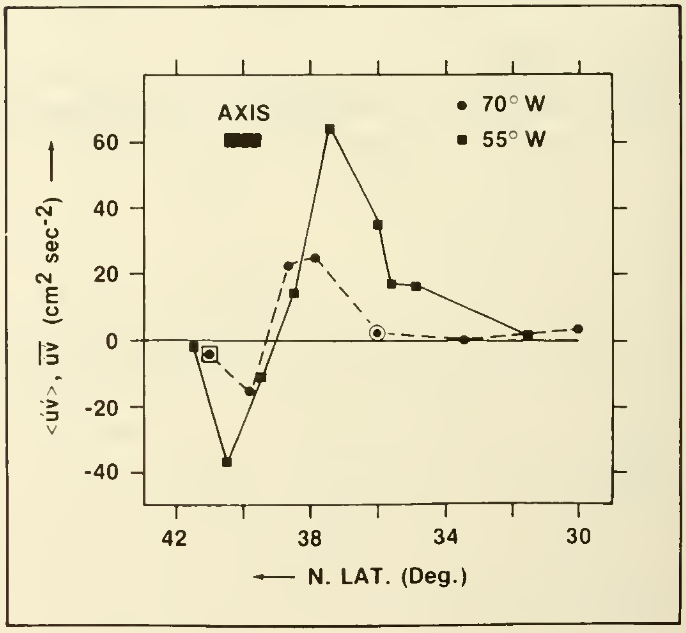
interested in the project, and with those working in other branches of oceanography and meteorology. As a result of this meeting, two joint theoretical projects were initiated: a numerical modeling of eddy statistics in the POLYGON-70 region and observation comparisons; and a study of non-linear Rossby wave dynamics. Abstracts of all papers presented at the summer institute will be collected and published as a joint Soviet-American report.

2. CTD intercomparison aboard RV Akademik Vernadsky. Preliminary results of calibration and intercomparison of American and Soviet conductivity-temperature-depth (CTD) observations obtained during leg 3 of RV Akademik Vernadsky cruise 14 (October 16–29, 1976) are given in table 7. The expected standard deviations for each instrument were calculated from the quantizing internal; this was compared with the range of standard deviations obtained from joint lowerings. The observed values, which were preliminary estimates, were about two to three times the digitizing noise level when the CTDs were stopped at the bottom or top of the cast. The magnitude increased by 10 to 50 times the digitizing noise level when the CTDs passed through a sharp vertical gradient.

These trials showed that significant improvement in compatibility of data could be achieved by intercalibration. Observed differences were sufficiently great to question laboratory calibration standards and techniques. A recommendation was made to consider shipboard calibration facilities on Soviet POLYMODE ships.

3. R/V Akademik Vernadsky Current Meter Intercomparison. This intercomparison was carried out in October 1976. The primary purpose of the intercomparison was to compare velocity measurements at 4,000 m depth using U.S.S.R. and U.S. current meters on U.S.S.R. surface float moorings with measurements by U.S. current meters on U.S. subsurface moorings at the same level (see table 8.) The intercomparison was scheduled at an Array 2 mooring (#581) to minimize effort and cost. The United States prepared two 850 current meters to deploy on two U.S.S.R. moorings. The moorings were set about 5 km apart. Only a partial record was obtained from the 850 current meter on one Soviet mooring, and the 850 current meter on the other Soviet mooring was partially flooded on recovery and yielded no data.





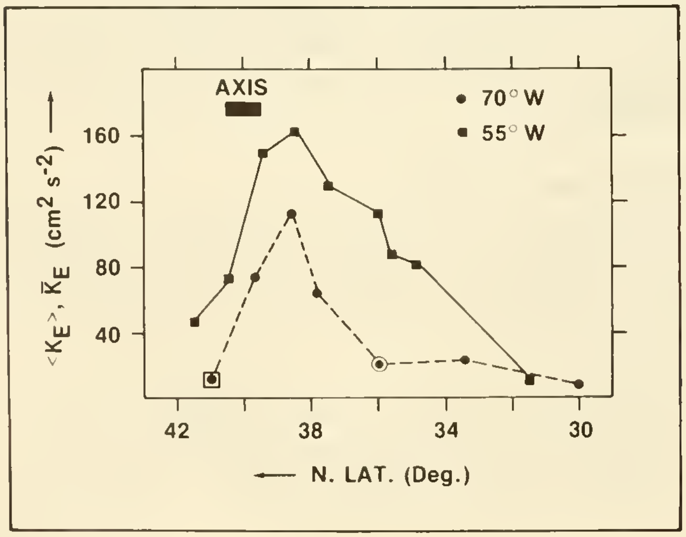
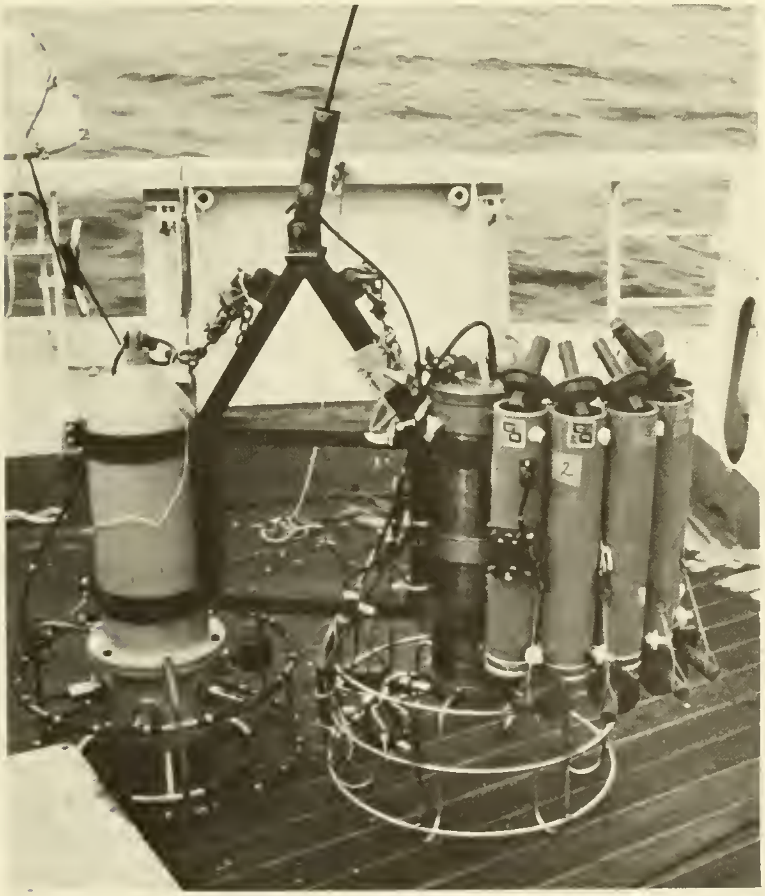


Figure 6.—Distribution of deep-current velocity statistics along 55°W (time averages indicated by solid line) and 70°W (space-time averages indicated by dashed line). Symbols ■ and • are for 4,000 m data, ⊙ for 5,000 m, and ⊡ for 2,000 m. The latitudes of the 70°W data have been shifted 2° north. Top) East-west velocity components; Middle) eddy kinetic energy; Bottom) off-diagonal horizontal Reynolds stress.

Table 7.—Standard deviations of differences for CTD intercomparisons

Expected from quantizing	ISTOK #26	ISTOK #10	AIST	W.H.O.I./Brown
Pressure (db)	0.24	0.22	0.23–0.35	0.03
Temperature (m°C)	2.7	2.7	2.1	.14
Conductivity (μ mho/cm)	2.6	4.2	3.5	.29
Shipboard estimate				
Pressure (db)	0.6	0.8	0.7	–
Temperature (m°C)	7–25	7–17	9–25	–
Conductivity (μ mho/cm)	11–30	11–18	13–30	–
Recalculated to minimize variance				
Pressure (db)	0.27–52	–	0.48–0.67	–
Temperature (m°C)	1.7 → 100	–	3.6 → 100	–
Conductivity (μ mho/cm)	6.2 → 100	–	10.3 → 100	–
Sampling rates (seconds per data scan)				
	1.449	1.433	1.256	0.03206



Arrangement of Soviet (left) and American conductivity-temperature-depth instruments during intercomparison experiments on RV Akademick Vernadsky *in the fall of 1976. (Photograph: R. Millard.)*

The Alexaev current meters on the Soviet surface moorings indicated higher speeds than American current meters on Soviet surface and American subsurface moorings. The results were as anticipated from previous intercomparisons carried out by SCOR Working Group 21. The speeds at 4,000 m were about 30% higher on the Alexaev current meters.

Local Dynamics Experiment

The scientific objectives of the Local Dynamics Experiment, scheduled to begin in summer 1977, include:

1. Studies of the kinematics and structure of the eddy field: spatial and temporal scales of the field, kinetic, and available potential energy of the eddies, phase relationships and phase velocities in the eddy field, etc. Evaluation of variability of the eddy properties in depth and horizontal directions.

2. Studies of the large-scale currents in the regions of investigation, variation of the currents in depth and time.

3. Studies of smaller-scale, higher-frequency phenomena in the ocean (internal waves, inertial currents, smaller-scale, higher-frequency structure), processes in the upper ocean, and their interaction with the eddies.

4. Studies of local dynamics of the eddy field proper. Vorticity balance in the mesoscale eddy field, energy exchange between adjacent eddies, heat and mass fluxes.

5. Studies of the eddy-mean flow interaction. Kinetic and available potential energy exchange between the mean flow and eddies.

6. Studies of the lower atmospheric processes related to ocean eddies.

Table 8.—Details of current meter and mooring intercomparison carried out from RV AKADEMIK VERNADSKY in October 1976

	U.S.S.R. BUOY #1	U.S.S.R. BUOY #2	U.S. (W.H.O.I.) BUOY #581
TYPE:	Surface	Surface	Subsurface
LAT:	34° 54.3′ N	34° 56.9′ N	34° 55.6′ N
LONG:	55° 02.7′ W	55° 02.3′ W	55° 04.7′ W
SET:	Oct. 7, 1976	Oct. 7, 1976	Dec. 17, 1975
RECOVER:	Oct. 20, 1976	Oct. 20, 1976	Oct. 17, 1976
Instrumentation Depths (m)			587-VACM
	584-DCM #1		
	588-ALEX		
		603-DCM #3	
	780-ALEX-12	799-ALEX-21	789 T/P
		801-DCM #4	
	990-ALEX-13	1001-ALEX-22	990-VACM
	993-DCM #2		
		1500-ALEX-23	1494-850
	4020-ALEX-14	3995-850	3995-VACM

ALEX —Alexaev current meter (U.S.S.R.)
DCM —digital current meter (U.S.S.R. Inst. of Oceanology, Moscow)
VACM—vector averaging current meter (W.H.O.I.)
850 —Geodyne Model-850 current meter (W.H.O.I.)
T/P —temperature/pressure recorder (M.I.T.)

The proposed site will be about 500 km in diameter and centered at about 29°N, 70°W. Table 9 shows the schedule for the experiment.

The Local Dynamics Experiment will consist of:

1. U.S.S.R. synoptic-scale mooring array. The array includes 19 moorings with 5 current-temperature meters per mooring (100, 300, 700, 1,500, 3,000, or 4,000 m) for July 1977 to July 1978. The sampling time interval is 30 minutes. The moorings will be located in a region of 300 km diameter and will be nearly equidistant in space.

2. U.S. mooring array. A closely spaced U.S. array of about eight moorings with 30 to 40 current meters and temperature-pressure recorders will be moored for about 1 year in May 1978. Distribution of instruments on the moorings will vary. One mooring will be densely instrumented from 250 m to the bottom, and all others will include instruments at 500, 600, and 700 m to estimate the terms of the quasi-geostrophic potential vorticity equation at a single point for a time period adequate to approach statistical stability.

3. U.S. SOFAR floats. A complementary U.S. mapping array of 60 free-floating neutrally buoyant SOFAR floats at two levels, 750 and 2,000 m, will be deployed. At least half of the floats will be deployed in February 1978 and the remainder in April 1978 in the moored array region (see 1 and 2 above) at a space interval of about 20 km. The floats function as Lagrangian velocity devices through land-based tracking stations, thereby limiting the geographical region in which they may be used. They also telemeter average temperature. Past experience suggests that once deployed they may be tracked for up to 3 years.

4. Density surveys. CTD and XBT surveys will be made from Soviet and American ships as follows:

a) XBT and CTD surveys of an area about 500 km in diameter will be made once every 40 days during the year from July 1977 through July 1978; sampling space interval is 30 km. The region circumscribes the arrays of 1, 2, and 3 above.

b) CTD–XBT surveys at about 25 km spacing over a region about 200 km diameter are to be completed in 6 days and repeated five times consecutively. The profiles will extend from surface to bottom and include continuous oxygen determinations and some water sampling for silicate, nitrate, and phosphate analysis as required. This work will be performed from May to June 1978 in a region within the larger array. (See 1, 2, 3 above.)

Part a will be performed by Soviet ships from July through Nov. 1977 and from March through June 1978; American and Soviet ships will make the surveys from Dec. 1977 through Feb. 1978. Part b will be performed by U.S. ships.

5. Additional U.S. elements for the intensive balance-of-terms experiment. This is a high-accuracy, closely sampled (10 km) synoptic (6 days), repeated (5 realizations), four-dimensional, U.S. hydrographic (CTD) sur-

vey embedded within the larger synoptic array (1, 2, 3, and 4 above) and concentrated from May through June 1978. The position, depth, and time of sampling will be varied to objectively map local dynamics. Sampling will include data from the U.S.S.R. current-meter array (1 above), U.S. current-meter array (2 above), the SOFAR float array (3 above), the U.S.-U.S.S.R. hydrographic survey (4 above), as well as velocity profilers to provide vertical structure of currents, near-surface current measurements to provide accurate velocity data in the highly energetic mixed layer, remotely tracked surface drogues to define the surface signals, and, possibly, a few short-term meteorological buoys to record surface atmospheric parameters.

6. Additional Soviet experiments. Smaller scale U.S.S.R. experiments include an upper layer experiment and an internal waves experiment. For these objectives the U.S.S.R. will do the following: (a) Two additional moorings will be added to the main U.S.S.R. mooring array, one with 5 current-temperature meters and the other with 15 current-temperature meters within a layer from 50 m through 4,000 m; b) Several CTD and temperature surveys of a region tens of kilometers in scale will be made; c) Measurements of air temperature, wind velocities, atmospheric pressures, humidity, solar radiation, and surface waves will be made from U.S.S.R. ships.

MODE and POLYMODE Data

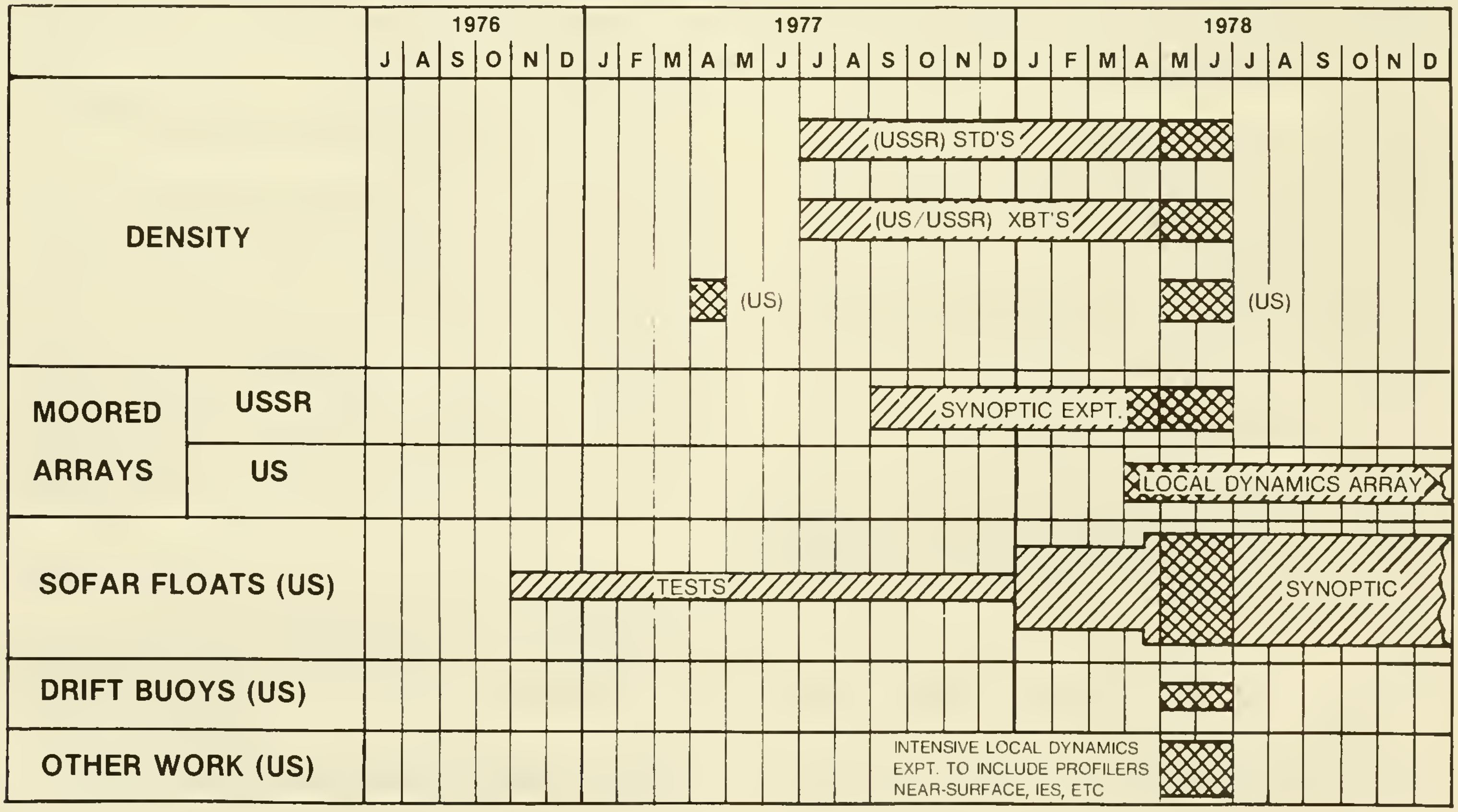
MODE and POLYMODE data are available from NODC as follows:

NODC Accession No.: 77–0261
Organization: Scripps Institution of Oceanography
Investigators: C. S. Cox, J. H. Filloux and D. Cayan
Grant No.: NSF/GX–36933, NSF/GA–31342
Project: MODE–I Bottom-Mounted Instruments
Data: Eastward and Northward components of electric field, expressed in 10^{-8} volts/meter, recorded every 64 seconds from March 21, 1973 to July 8, 1973, with a break for servicing. The data were obtained in the MODE area and comprise 7 files on NODC-compatible magnetic tape.

NODC Accession No.: 77–0231
Organization: Scripps Institution of Oceanography, Institute of Geophysics and Planetary Physics (SIO/IGPP)
Investigators: W. S. Brown, W. H. Munk, F. E. Snodgrass, H. Mofjeld, and B. Zetler
Grant Nos.: NSF/GX–29052 and NSF/AG–253 (Mojfeld)
Project: Bottom-Mounted Instruments
Data: 12,568 pressure measurements of MODE Deep Sea Tides from 5 sea-floor capsules at the MODE site, March 18, 1973 to July 9, 1973. Data received on punch cards.

NODC Accession No.: 76–1423
Organization: Massachusetts Institute of Technology
Investigator: G. Seaver
Grant No.: NSF/IDO75–04215
Project: MODE XBT's
Data: 341 MODE XBT's taken aboard RV Chain Cruise CH–118, January 22, 1975–February 2, 1975. Data were submitted in log sheets and strip charts.

Table 9.—Schedule for POLYMODE local dynamics experiment



NODC Accession No.: 76-1261
Organization: Massachusetts Institute of Technology
Investigator: G. Seaver
Grant No.: NSF/IDO75-04215
Project: MODE XBT's
Data: 311 MODE XBT's taken aboard RV Chain Cruise CH-122, May 25, 1975 to June 7, 1975. Data were submitted on log sheets and strip charts.

NODC Accession No.: 76-1247
Organization: Massachusetts Institute of Technology
Investigator: C. Wunsch
Grant No.: NSF/IDO75-03998
Project: POLYMODE II-1-FAME-IIWA2
Data: Temperature and pressure values from current meter moorings in the POLYMODE area f om April 29, 1975 to January 26, 1976, submitted on NODC-compatible magnetic tape.

NODC Accession No.: 76-0702
Organization: Woods Hole Oceanographic Institution
Investigator: P. Richardson
Grant No.: NSF/IDO75-08765
Project: MODE XBT's
Data: 372 MODE XBT's in MODE area taken aboard RV Trident Cruise TR-175 November 20, 1975 to December 10, 1975. Data were submitted on log sheets and strip charts.

NODC Accession No.: 75-0818
Organization: Woods Hole Oceanographic Institution
Investigator: W. J. Schmitz
Grant No.: NSF/IDO75-03962
Project: MODE Moored Current Meter Arrays
Data: 413 XBT's taken aboard RV Knorr Cruise K-49 in the MODE area from April 21, 1975 to May 19, 1975. Data were submitted on log sheets and strip charts.

NODC Accession No.: 75-0782
Organization: Woods Hole Oceanographic Institution
Investigator: P. Richardson
Grant No.: NSF/IDO75-08765
Project: MODE XBT's
Data: 319 MODE XBT's in MODE area taken aboard RV Trident Cruise TR-168, May 24, 1975 to June 11, 1975. Data were submitted on log sheets and strip charts.

MODE and POLYMODE Bibliography

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North Pacific Experiment (NORPAX)

The long-term objective of NORPAX is to understand fluctuations in the upper layers of the North Pacific Ocean and their relation to the overlying and adjoining atmosphere. These fluctuations have time scales of months to years and a space scale in excess of 1,000 km. Achievement of this goal should lead to improved prediction of weather and climate for the northeast Pacific Ocean and North America. NORPAX is working to attain its long-range objective through analysis of historical data, experiments to identify and understand important processes, monitoring of low-frequency fluctuations, and integration of observations with theoretical and numerical studies.

NORPAX is jointly sponsored by the NSF, IDOE Office and the Office of Naval Research. The coprincipal investigators form the nucleus of NORPAX (table 10). They annually elect an executive committee that oversees the entire program, formulates plans and policy, coordinates activities requiring cooperation, and represents NORPAX in dealing with the granting agencies and the rest of the scientific community. The five members of the executive committee select a chairman who is assisted by the program administrator.

Most principal investigators belong to at least one of the various groups and task forces formed within the program. These groups are related to certain scientific problem areas (Climate Group), to specific experiments (Anomaly Dynamics Study, Equatorial Program) or to important organizational tasks (XBT Panel, Satellite Data Evaluation Panel). Membership in these groups is voluntary and by self-appointment; scientists who are not NORPAX investigators, but who are willing to contribute to the program, may also be members of these groups.

Climate Studies

The objectives of the Climate Studies are to understand long period, large scale, temperature and circulation changes in the North Pacific and to relate these cnanges to variations in atmospheric circulation.

Perhaps the most striking accomplishment of the Climate group was the prediction of the abnormal winter weather of 1976–77 in the United States. This forecast is given in figure 7. Temperatures were forecast in three categories: below, near, and above normal, each category having equal climatological probability of occurrence as determined from 30 years of record. Similarly, precipitation was also forecast in three likely categories: light, moderate, and heavy. Forecasts for both elements show appreciable skill. They were mainly based on a computerized model of large-scale air/sea interactions developed for the North Pacific. More specifically the sea-surface temperature patterns in the fall were predicted kinematically to evolve into a winter pattern. This was then translated by the model into a compatible midtropospheric (atmospheric) flow pattern, which indicated an abnormally strong Aleutian low with its maximum anomaly centered at 50°N, 180°W. This prognosis made it possible to use a newly developed set of teleconnections (cross-correlations) (fig. 8) to predict a strong ridge over western North America and a strong trough over the U.S. east coast, which brought frigid air and snows to the eastern two-thirds of the United States and drought to the Far West.

During the past year, climate group scientists have also been engaged in a study of seasonal and interannual fluctuations of the Subtropical Gyre in the western North Pacific from 1954 to 1974. To accomplish this, temperature data from historical mechanical bathythermograph (MBT), expendable bathythermograph (XBT), and hydrographic data files were combined. From this combined data set, the seasonal climatology at standard depths (down to 400 m) was computed. Also computed was the integral of temperature, called "steric height," as shown in figure 9. This parameter shows significant seasonal variability, particularly in the center of the Subtropical Gyre at 17.5°N, in the ridge between the North Equatorial Current and the North Equatorial Countercurrent at 7.5°N, and in the region of the Kuroshio south of Japan at 33°N. The Subtropical Gyre and the component currents are most energetic in the spring and summer, and least energetic in the fall and winter.

Figure 10 shows the annual climatology of steric height anomaly for the western North Pacific, together with a 20-year record of the relative surface current speed for the major zonal currents in this part of the North Pacific Ocean. All these currents show a significant seasonal cycle, together with substantial year-to-year changes. The Kuroshio (not shown in fig. 10) and the North Equatorial Countercurrent fluctuate from year to year more or less in phase, but out of phase with the strength of the North Equatorial Current and the Subtropical Countercurrent.

These results show that the equatorial and midlatitude portions of the Subtropical Gyre are linked in a definite way, indicating that the entire Subtropical Gyre must be studied if variability in any one part is to be understood.

Anomaly Dynamics Study

The objective of the Anomaly Dynamics Study is to explain the origin of the large heat storage anomalies that are observed in the surface layer of the Pacific Ocean. One im-

Table 10.—U.S. institutions, investigators, and projects in NORPAX

Institutions	Investigators	Projects
University of Alaska	T. C. Royer	Circulation and Heat Content Fluctuations in the Subpolar Gyre and Their Atmospheric Coupling
University of British Columbia	M. Miyake	AXBT Measurements in the North Pacific Ocean
California Institute of Technology, Jet Propulsion Laboratory	M. T. Chahine	Remote Sounding of Temperature of the Oceanic Surface in Cloudy Atmosphere
University of California, San Diego, Scripps Institution of Oceanography	R. L. Bernstein and W. B. White	Low-Frequency Baroclinic Responses of the North Pacific Current to Interannual Variability in the Westerly Winds
	N. E. Clark	Interannual Variability of Large-Scale Heat Exchange Across the Air-Sea Interface in the Eastern North Pacific Ocean
	R. E. Davis	Upper Ocean Dynamics
	R. E. Davis and R. Knox	Monitoring Equatorial Currents in the Central Pacific
	G. J. McNally	Satellite-Tracked Drifting Buoys
	J. Namias and T. P. Barnett	Large-Scale and Long-Term Ocean Atmosphere Coupling Over the Pacific and Remote Weather and Climate Influences
	W. C. Patzert	Analysis and Publication of El Niño Cruise Data
	W. C. Patzert	A Cooperative Experiment To Measure Equatorial Currents
	W. C. Patzert and T. P. Barnett	Aircraft Monitoring of Equatorial Currents
	R. T. Wert and M. J. Desruisseaux	Administration
	R. T. Wert and S. Pazan	Data Program
	W. B. White	Year-to-Year Variability in the Thermal Structure of the Subtropical Grye of the Western North Pacific Ocean
	W. B. White and R. L. Bernstein	Hydrographic Measurements of the North Pacific Current
Center for the Environment and Man, Inc.	C. A. Jacobs	Numerical Modeling of Possible Endemic Generating Mechanisms of the North Pacific Ocean Temperature Anomalies
University of Hawaii	R. Harvey	Equatorial Current Measurements
	L. Magaard	Baroclinic Rossby Waves in the North Pacific
	J. C. Sadler	Pacific Cloudiness and Atmospheric Anomalies
	M. J. Vitousek	Line Islands Monitoring
	K. Wyrtki	The Interaction of Circulation, Sea Level, Heat Storage, and Winds Over the Pacific
	K. Wyrtki and A. Bainbridge (SIO)	Oceanographic Shuttle Between Hawaii and Tahiti

Table 10.—U.S. institutions, investigators, and projects in NORPAX (Cont.)

Institutions	Investigators	Projects
NOAA/AOML	D. Hansen	Drifter Measurements in the North Equatorial Countercurrent
NOAA/National Marine Fisheries	J. F. T. Saur and D. R. McLain	Ships of Opportunity Time Series XBT Sections for the Eastern North Pacific Ocean
NOAA/PMEL	D. Halpern	Transport of the North Equatorial Countercurrent in the Central Pacific
US Naval Oceanographic Laboratory	H. E. Hurlbert, J. D. Thompson, and S. A. Piacsek	A Numerical Investigation of the Time-Dependent Circulation of the Equatorial and Eastern Pacific
USN/Fleet Numerical Weather Central	R. E. Hughes	Ships of Opportunity XBT Program
USN/Naval Postgraduate School	R. L. Haney	Numerical Simulation of the Coupled North Pacific Ocean-Atmosphere System
Oregon State University	W. L. Gates	Research on the Dynamics of the Mixed Layer and Its Role in the Oceanic General Circulation
San Diego State University	C. E. Dorman	Variability of the Oceanic Thermal Structure Between San Francisco and Hawaii
Texas A&M University	W. Emery	Computation of Density From Measurements of Thermal Structure
	A. D. Kirwan	Anomaly Dynamics Study
University of Tokyo	H. Solomon	The Role of Subpolar Western Boundary Currents in Large-Scale Ocean Atmosphere Coupling in the North Pacific
University of Washington	B. A. Taft	Study of Thermocline Fluctuations of the Pacific North Equatorial Current

Predicted for winter (December, January, February) 1976-77

Completed December 1, 1976 from data ending November 23, 1976

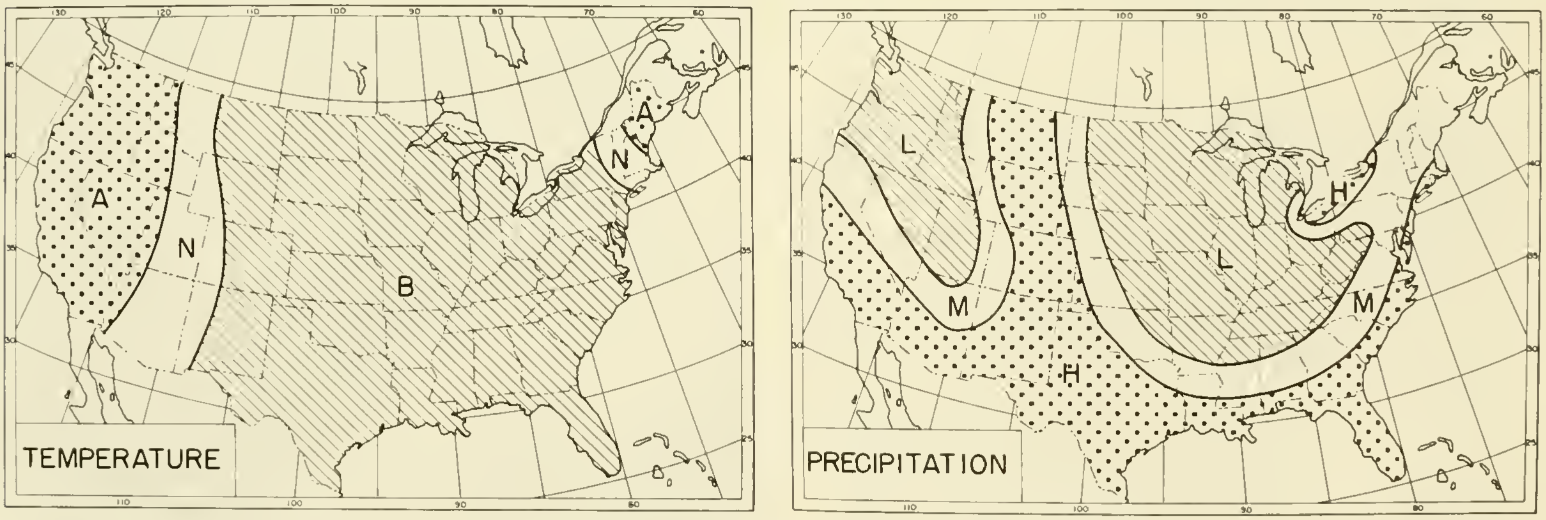


Figure 7.—Forecast of J. Namias for December, January, February 1976-77. A=above normal, N=near normal, B=below normal, L=light, M=moderate, H=heavy.

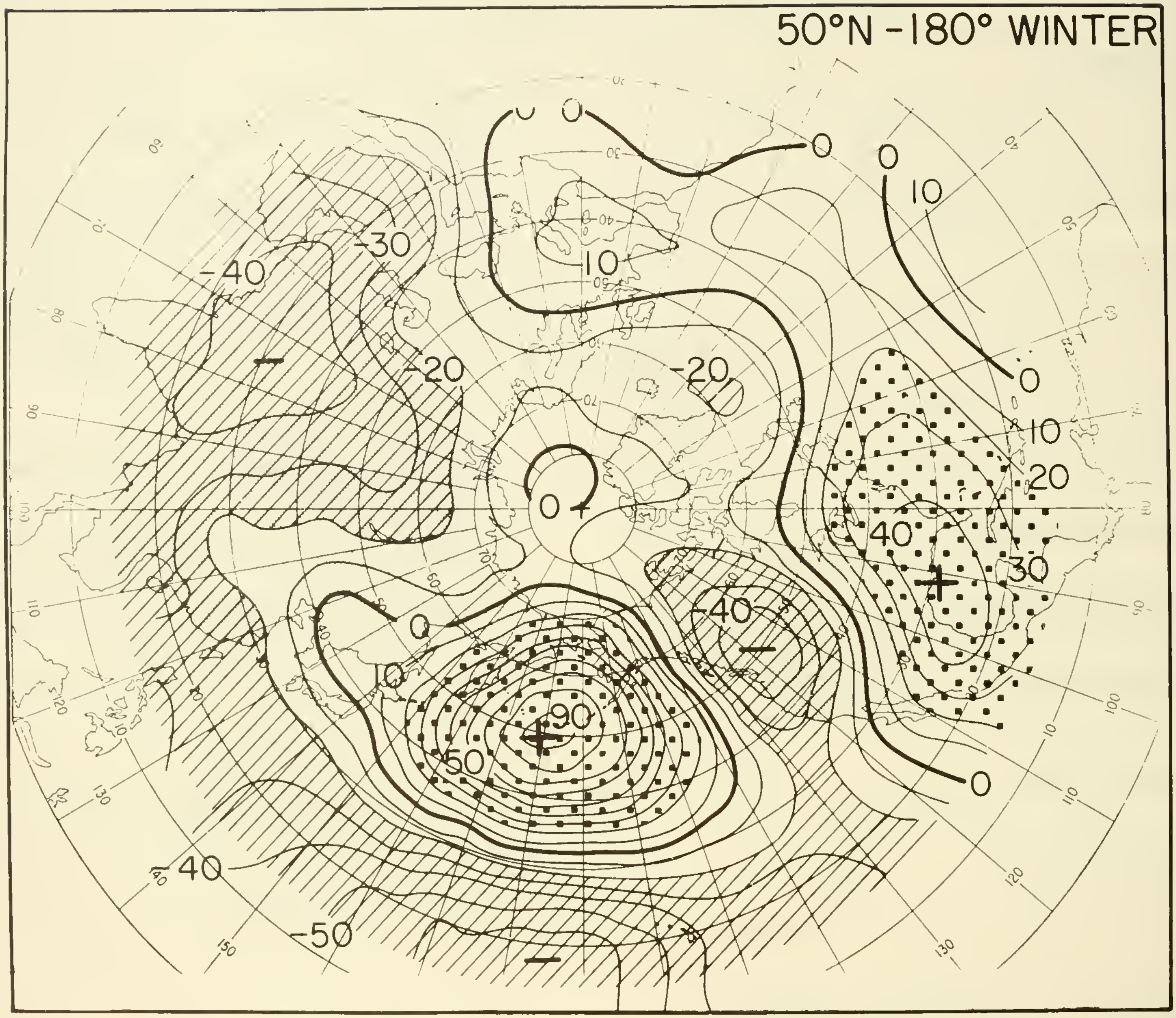


Figure 8.—Teleconnections (cross-correlation) of 700-mb pressure height departure from mean for Northern Hemisphere winter. (Source: J. Namias.)

portant part of the program is regular monitoring, by aircraft and merchant ships, of the thermal structure of the ocean's upper layer in the region 30° to 50°N, 140° to 180°W. Additionally, three research vessels made cruises to this region, closely spaced STD and XBT measurements were taken, and 16 drogued surface drifters were launched on each cruise. The first two cruises were on KANA KEOKI in June 1976 and on WECOMA in September 1976. The third cruise was made on the RV THOMPSON in May 1977.

Preliminary results from the first two cruises are illustrated in figures 11 and 12. Figure 11 shows the temperature distribution that was observed at 400 m depth. The subarctic front shows a nearly east-west orientation, especially at more northern latitudes (40° to 50°N). The temperature difference at 400 m between the two cruises shows "striations" running WSW-ENE that are parallel to the general atmospheric circulation. Figure 12 shows the tracks for the surface drifters in September 1976. The drifters in the northern portion of the region show very little north-south displacement while those in the southern portion have substantial north-south displacements and even easterly (as opposed to the dominant westerly) displacements. Additional efforts are underway to merge these data sets and to seek explanations for the observed temporal differences in terms of Ekman pumping by storms.

Equatorial Program

The overall objectives of the NORPAX Equatorial Program are to observe and explain large scale, long period fluctuations in the equatorial Pacific current system. This Program derives its inspiration from two sources. First, oceanographers wish to understand the mechanisms by which the equatorial current system produces anomalous temperature

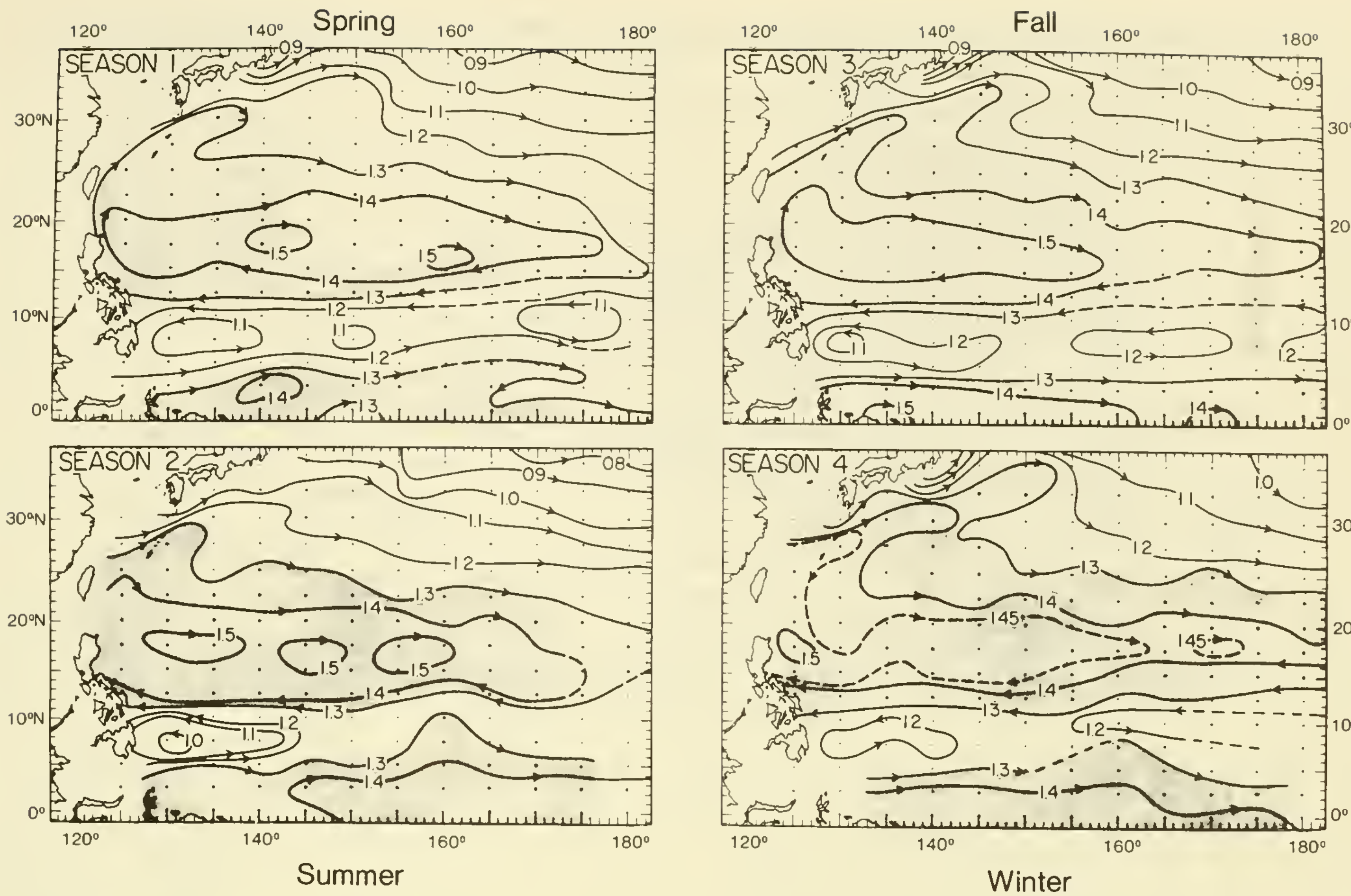


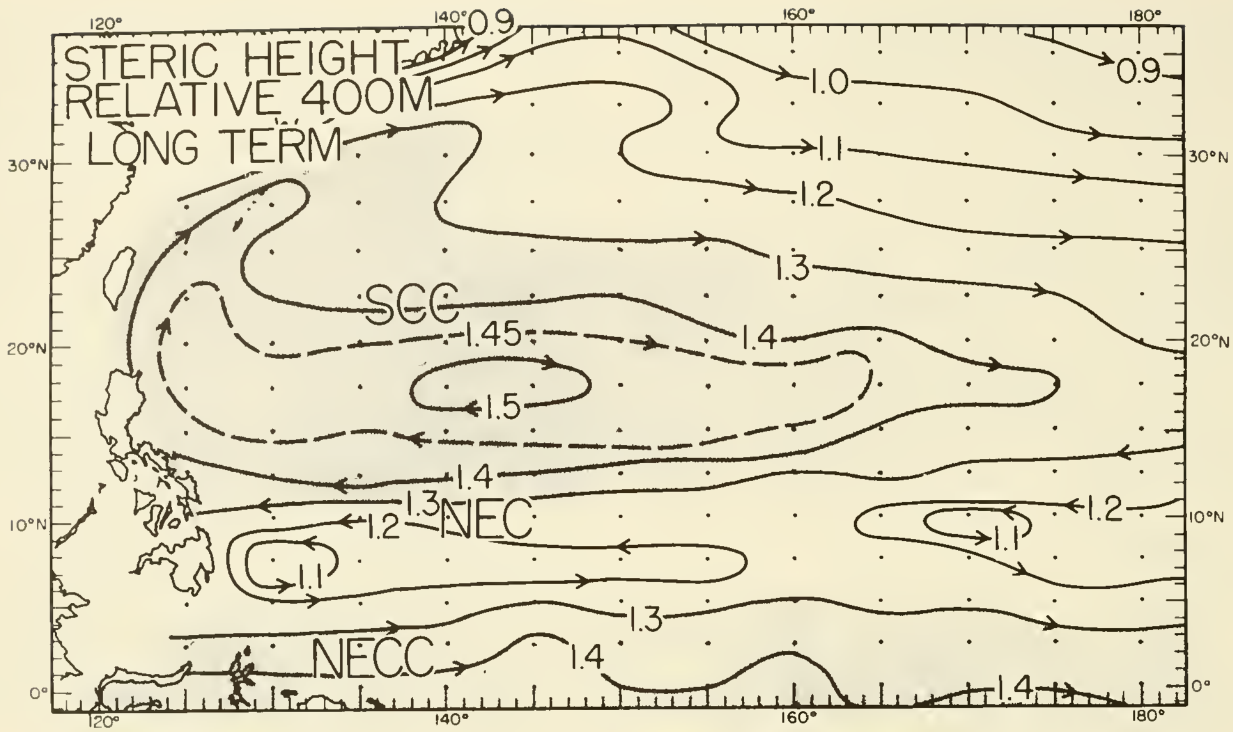
Figure 9.—Steric height anomaly in dynamic meters at 400 m.

Launching a drifter from RV WECOMA

structure. Anomalous ocean temperature structure is especially important at low latitudes because it dramatically influences the commercial fishery and the circulation of the atmosphere. Second, oceanographers want to interact with meteorologists and climatologists during the First GARP Global Experiment (FGGE) in 1978–79. During FGGE, special aircraft, satellites, and ship observations will be made to provide wind stress and heat flux data of excellent quality and in unprecedented quantities.

The NORPAX Equatorial Program will begin in the fall of 1977 with a 3-month pilot experiment. One of the principle objectives of the pilot experiment is to determine the optimal observational strategy to be used for a larger oceanographic effort to be mounted later during FGGE. The pilot equatorial program essentially consists of a number of individual but closely coordinated observational projects located on or near the 150° west meridian between the latitudes of Hawaii and Tahiti (fig. 13). Measurements will be taken from ships, airplanes, moored instruments, and island stations. The resulting data will be used in the following ways:

1. The space and time scale variability of density and velocity field will be used to design minimum but adequate sampling schemes for future monitoring of long-term variations.



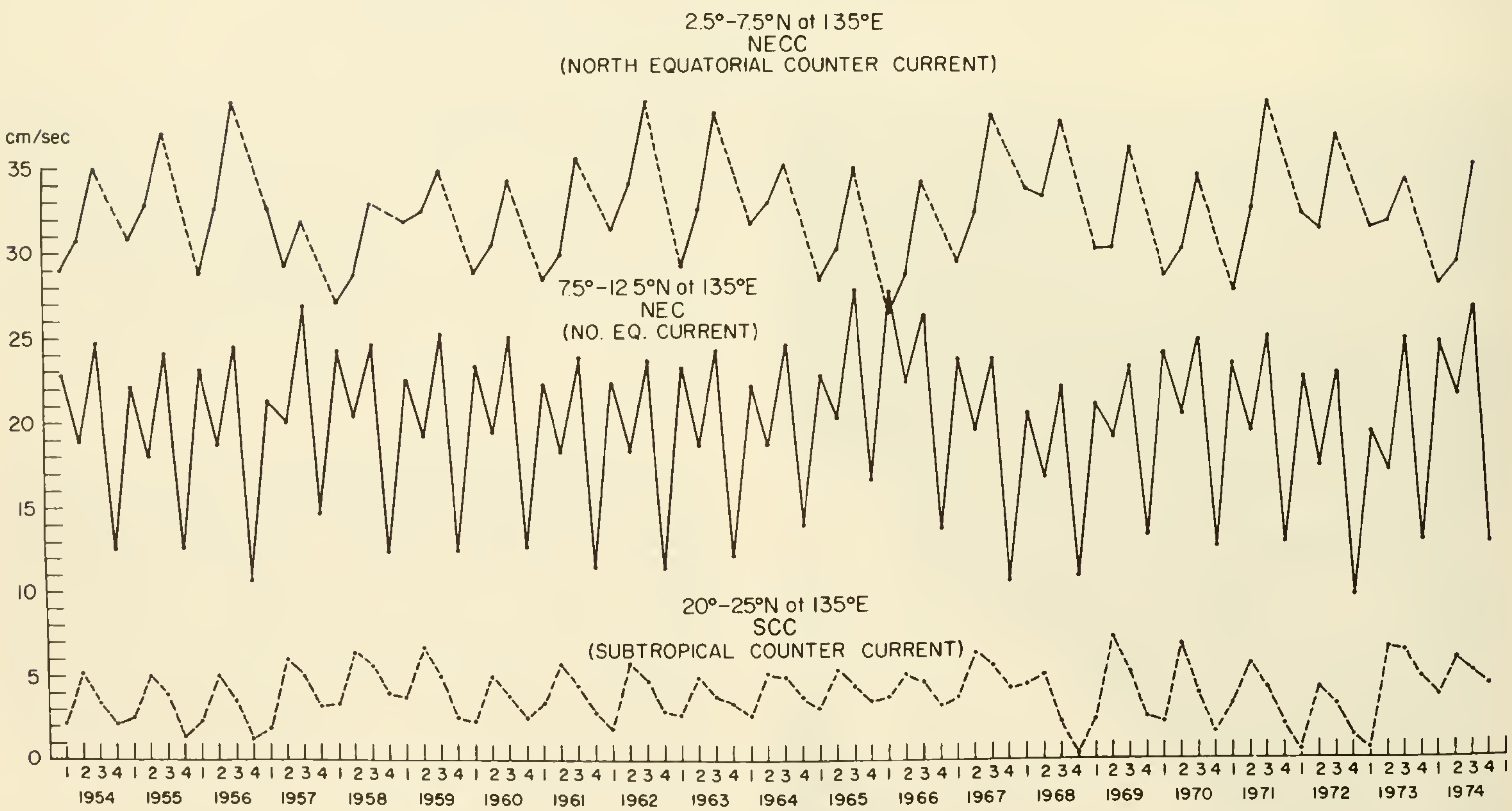


Figure 10.—Annual steric height anomaly in dynamic meters and 20-year record of relative surface current speed for major currents.

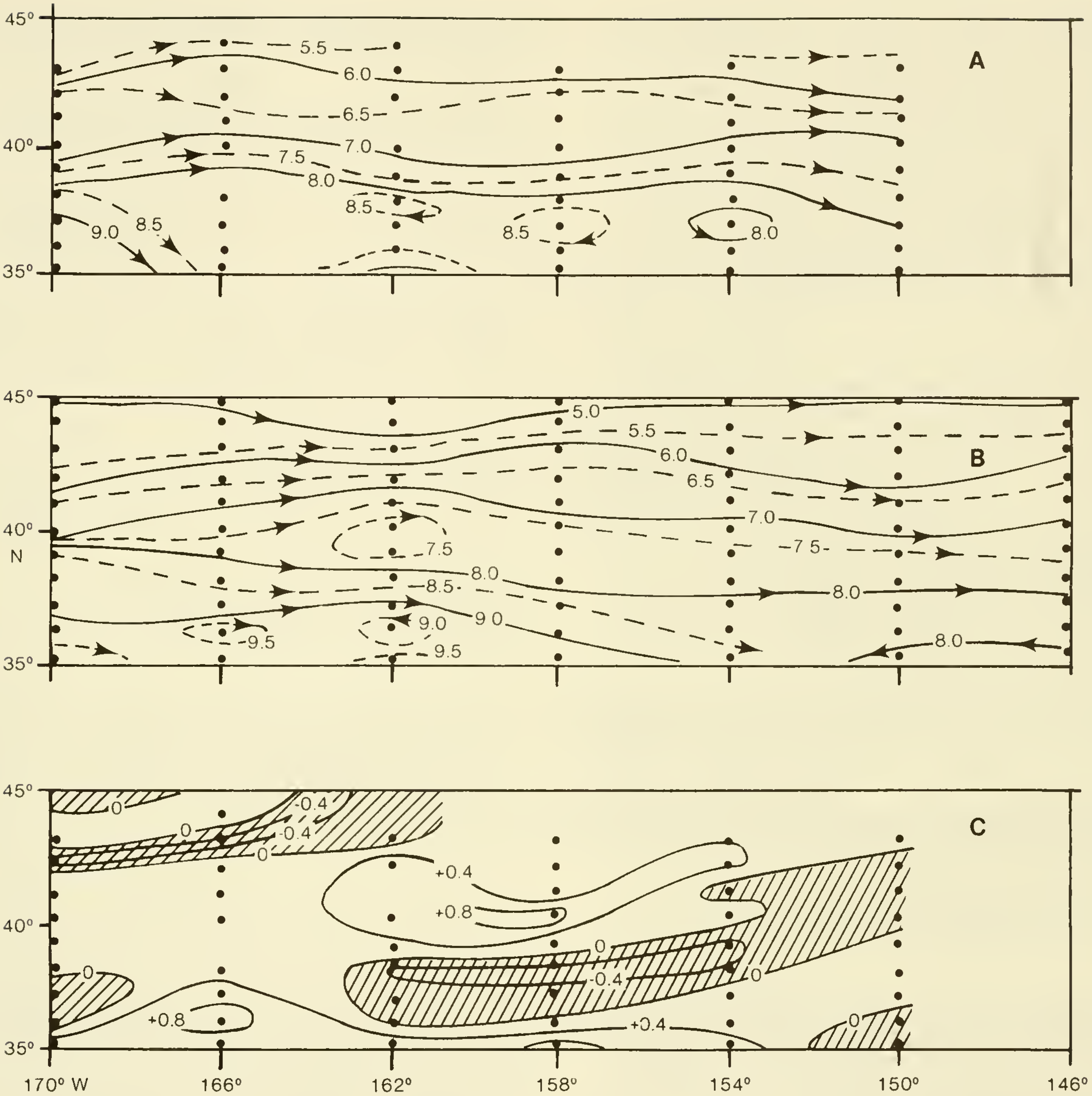


Figure 11.—Temperature (°C) distrbution at 400-m depth in Eastern North Pacific. A) June 1976; B) September 1976; C) temperature difference, September minus June.

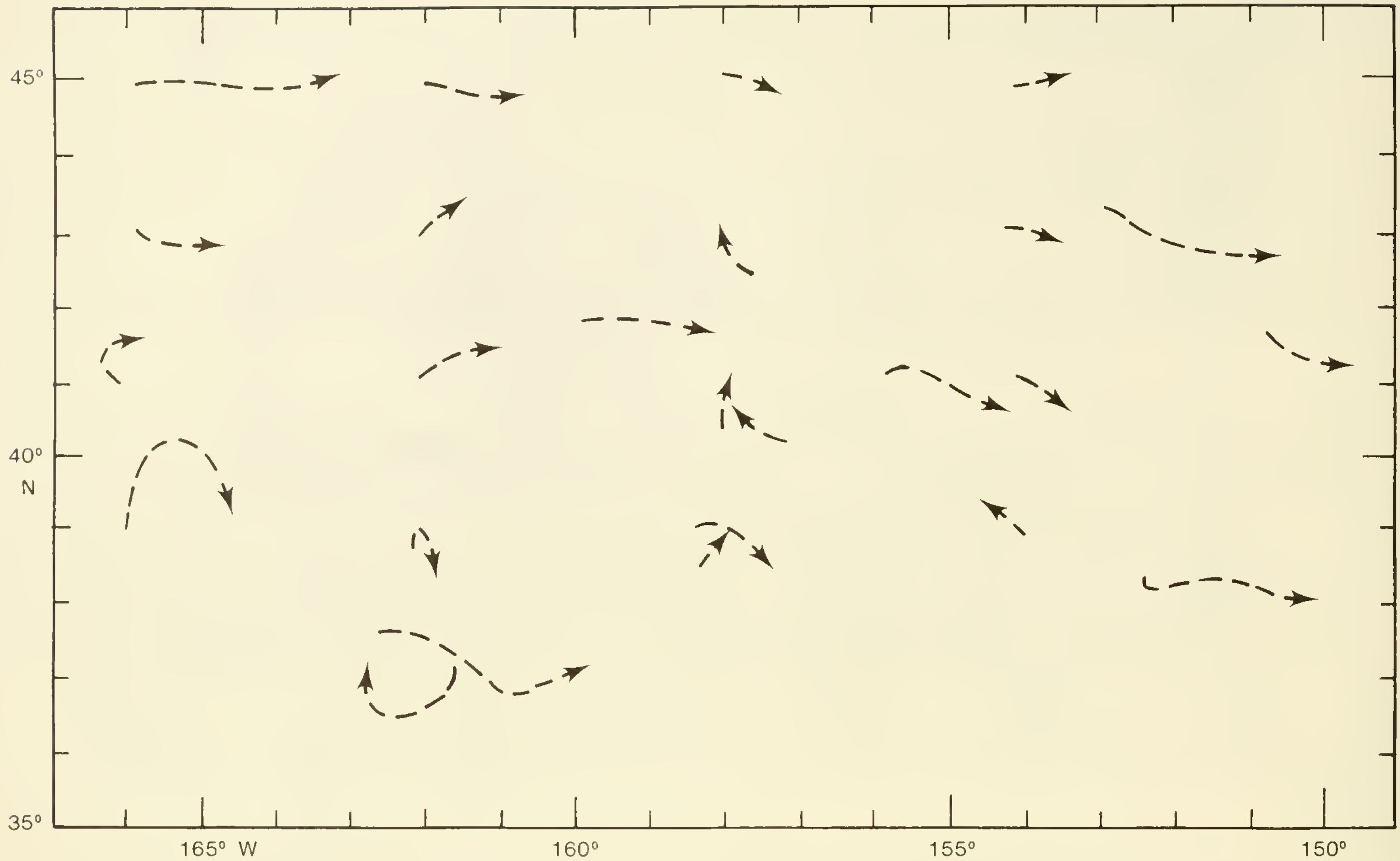


Figure 12.—Trajectories of surface drifters for September 1976.

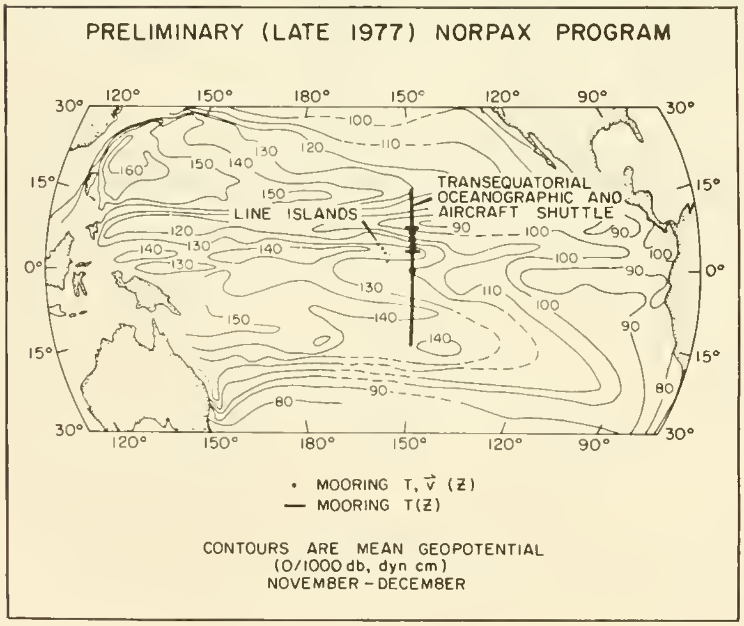


Figure 13.—NORPAX Equatorial Program details and Equatorial Pacific geopotential contours.

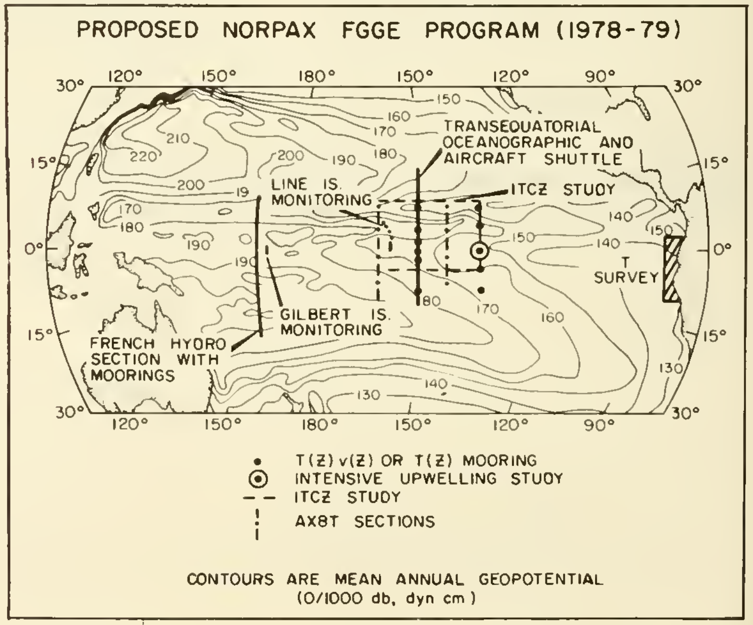


Figure 14.—Elements of NORPAX/FGGE program and mean annual geopotential contours.

2. Directly measured currents will be compared with geostrophic calculations based on shipboard hydrographic data.

3. Relative geostrophic currents based on temperature observations from aircraft and ships will be compared with those based on complete hydrographic data.

4. The feasibility of monitoring upper layer equatorial currents using drifting buoys and moored current meters will be determined.

5. The feasibility of monitoring thermal structure and, indirectly, transport using XBT's dropped from commercial vessels and/or aircraft will be examined. If adequate coverage could be achieved, this would be one of the most economical of all monitoring techniques.

6. Atmospheric observations from island stations and ships will be used to relate changes in the ocean and the atmosphere. Island station and ships data are essential to equatorial meteorology because of the vast expanses of open sea.

7. Sea level fluctuations, as measured from island tide gauges, will be compared against geostrophically computed and directly measured currents. Tide gauge records provide the longest time series data related to current fluctuations.

During FGGE several countries in the Pacific area will be carrying out equatorial observational programs. For example, the French laboratory at New Caledonia intends to do hydrographic sections and current measurements in the western Pacific and the Japanese intend to do related work in the western Pacific. A major part of the U.S. effort will be carried out by NORPAX investigators.

The fundamental conceptual framework or hypothesis of the NORPAX Equatorial Program is that variations of large scale zonal currents in the central tropical ocean, induced by low frequency fluctuations in the trade winds, cause large scale changes in the heat content of the upper layers of the eastern tropical Pacific. This framework is subject to modification as a result of pre-FGGE experiments, but a FGGE-related observational program, based on that framework, has already been tentatively outlined. The elements of that program are (see fig. 14):

1. Meridional hydrographic sections to monitor the density structure and, indirectly, the currents.

2. Direct current observations, especially close to the Equator where the computation of geostrophic currents is not possible.

3. General oceanographic observations from small boats based at island stations.

4. Observations of the thermal structure in the far eastern equatorial Pacific where mid-ocean disturbances eventually interact with the coast. This may be done through a ships of opportunity program or through cooperation with research institutes in Ecuador or Peru. The international cooperation option will be explored by SCOR Working Group 47 on FGGE oceanography.

5. The Intertropical Convergence Zone (ITCZ) is the region where a major portion of the heat is supplied by latent heat flux to the atmosphere. An experiment to investigate the relationship between sea surface conditions in the ITCZ and ocean-atmosphere interaction might be performed during two periods when the convergence zone is sharply defined and relatively stable in position (January to February and May to June 1979).

The knowledge gained during FGGE will be applied to the design of a continuing equatorial Pacific monitoring network. This network will assist in achieving NORPAX long range goals.

NORPAX Data

NORPAX data are available from NODC as follows:

NODC Accession No.: 77–0162
Organization: Scripps Institution of Oceanography
Investigators: W. J. Emery and R. T. Wert
Grant No.: NSF/OCE74–24583
Project: Mean T/S Curves in the Pacific
Data: These data result from processing all NODC holdings of station data and BT data in the Pacific. The processed results are mean T/S curves for the Pacific Ocean. They were submitted on NODC-compatible tape and are also available as a published data report.

NODC Accession No.: Held at National Climatic Center
Organization: University of Hawaii
Investigator: J. C. Sadler
Grant No.: NSF/GX–42007
Project: Pacific Cloud Atlas
Data: Daily values of total cloud cover in OCTAS for each 2½° lat. by 2½° long. grid square over the Pacific Ocean for the area 30° S to 60° N and 105° E to 75° W, derived from daily nephanalysis prepared from meteorological satellites. The data were submitted on magnetic tape.

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International Southern Ocean Studies (ISOS)

ISOS is concerned with understanding the long-term, large-scale variability of dynamical processes in the Southern Ocean. It consists of a series of experiments to determine global atmospheric and oceanic circulation and their interaction. The project has focused on the dynamics of the Antarctic Circumpolar Current, the First Dynamic Response and Kinematics Experiment (F DRAKE), but studies have been made of bottom-water formation and the Polar Front. The objectives of ISOS and F DRAKE cruises are to:

1. Identify the statistical properties and space-time scales of variability in selected regions of the Antarctic Circumpolar Current system.

2. Subject to critical test theories of local dynamical balance, mixing, and exchange with other oceans.

3. Develop a basis for understanding the role of large-scale circulation and air-sea interaction in the Southern Ocean in global climate dynamics.

These objectives will be met through a sequence of monitoring and dynamics experiments in several regions of the Antarctic Circumpolar Current System (ACCS), long-term monitoring of certain large-scale properties, analysis of existing data sets, and numerical, analytical, and laboratory modeling. ISOS projects are listed in table 11.

F DRAKE (First Dynamic Response and Kinematics Experiment)

The first such experiment, F DRAKE, combines both a monitoring effort and local experiments. It began in the austral summer of 1974–75 and will terminate in 1977. The goals of F DRAKE are: 1) to describe the energy-containing space and time scales in the Drake Passage in order to design a long-term transport-monitoring experiment for the ACC to be carried out during FGGE; and 2) to describe selected property distributions within the Drake Passage and the Western Scotia Sea for the continuing study of mixing processes, particularly in the Polar Front Zone (PFZ), which are involved in the formation of Antarctic Intermediate Water.

To assess the spatial and temporal variability of the currents and to estimate the yearly, mean flow at 2,700 m depth in the Drake Passage, an array of 15 moorings instrumented with current meters was deployed in March 1975. The array consisted of 7 short-term (20 days duration) and 8 long-term (1-year duration) moorings. The short-term array of 15 moorings was designed to study spatial variability; the long-term array to study temporal variability and to estimate a mean flow. During the short-term experiment, 14 current meters yielded current measurements at an average depth of 2,750 m; during the long-term experiment, six current meters recorded velocity at a mean depth of 2,750 m for more than 250 days. An autocorrelation function from down-channel velocities was calculated for each long-term current record. The period of the first zero-crossing of the autocorrelation function, which averaged 14 days, was used as an estimate of the time-scale of independent sampling of the low-frequency velocities.

Cross-correlation coefficients between down-channel velocities for each pair of moorings were not significantly nonzero at 95 percent confidence limits even for the smallest long-term mooring separation of 80 km. Fourteen-day averaged velocities for the short-term array of 14 moorings (fig. 15) illustrate the spatial noncorrelation. This noncorrelation may be due to control of the currents at 2,750 m depth by small-scale bottom topography that rises to depths as shallow as 2,400 m. The preferred explanation for the low correlation is that the low-frequency velocities vary over spatial scales smaller than the mooring separations. In other ocean experiments, velocities have been found to vary over spatial scales the size of the Rossby radius of deformation. Estimates of the Rossby radius, based on measurements of temperature and salinity versus depth near 60°S, is 15 km. Thus, variations of low-frequency currents may occur over distances of 15 km, and nonsignificant correlations over separations of 80 km are not unexpected.

To estimate the spatial variability of the currents, a mean velocity at 2,750 m in the Drake Passage for each 14-day period and a variance about that mean are calculated from the six long-term current records. An estimate of the standard deviation for the population of current measurements at 2,750 m in the Drake Passage is taken as the square-root of the average variance, which equals 4.8 cm/s.

The mean down-channel flow at 2,750 m depth in the Drake Passage is estimated for each 14-day period (fig. 16) by averaging the velocities available during each period. Errors, representing standard errors of the mean, are 1.3

Table 11.—U.S. institutions, investigators, and projects in ISOS

Institutions	Investigators	Projects
Columbia University	D. Giorgi	Circulation of the Southwest Atlantic Ocean
	A. Gordon	Southern Ocean Atlas
Nova University	M. Spillane	Quasi-Geostrophic Zonal Jets
Oregon State University	J. Allen	Theoretical Studies of Time- Dependent Flow in the Vicinity of Drake Passage
	L. Gordon	Chemical Observations and Interrelationships in the Southern Ocean
	V. Neal	International Coordination
	R. Pillsbury and H. Bryden	Study of the Long-Term Variability of the Antarctic Circumpolar Current in the Drake Passage
University of Southern California	T. Maxworthy and T. Spence	Laboratory Modeling Studies of the Antarctic Circumpolar Current
Texas A&M University	W. Emery	A Study of the Thermal Structure South of Australia
	W. D. Nowlin	Central Administration, Coordination, and Planning
	W. D. Nowlin	Chemical and Physical Oceanography of the Antarctic Circumpolar Current and Frontal Zones: I. Observations in the Drake Passage and Scotia Sea
University of Washington	D. J. Baker	Coordination of Monitoring Activities and Liaison With the Polar Experiment of the Global Atmospheric Research Program
	D. J. Baker and R. Wearn	Measurements of the Antarctic Circumpolar Current and Analysis of Existing Tidal and Meteorological Data
	R. Wearn	Study of the Density Structure and Variability in the Drake Passage Using Data Collected Aboard ARA ISLAS ORCADAS
Woods Hole Oceanographic Institution	T. Joyce	Dynamical Observations at the Antarctic Polar Front
	M. McCartney	Theoretical Modeling of Current-Bottom Topography Interactions in the Southern Ocean

cm/s during the short-term experiment and 2.0 cm/s during the long-term experiment. The mean 14-day averaged flow varies from −2.2 ("westward") to +4.8 ("eastward") cm/s over the measurement period of a year. In terms of errors, only two of these mean flows are significantly nonzero at a 95 percent confidence level. Both of the significant mean flows are "eastward."

It was hoped that the year-long averaged currents would be larger than their errors because of temporal variability and would exhibit less spatial variability than observed in the short-term experiment. Record-length mean velocities for the long-term experiment are generally larger than their standard errors because of temporal variability. Thus, the long-term measurements define mean velocities at the mooring sites. There is, however, a good deal of spatial variability shown in the long-term means. Estimates of the yearly averaged mean velocity at 2,750 m in the Drake Passage is 1.5 cm/s with a standard error owing to spatial variability in the long-term means of 1.1 cm/s.

To convert estimated velocities to transport, the fact was used that a down-channel flow of 1 cm/s over the entire width and depth of the Drake Passage is equal to a transport of water through the Passage of 25 Sv. With a constant baroclinic transport relative to 2,750 m depth, the variation in total transport because of observed temporal changes in the 14-day averaged mean flow is 175 Sv, which agrees with the variation of 130 Sv suggested by sea-level variations.

Because of the spatial variability in the observed currents, efforts to monitor the transport of the Antarctic Circumpolar Current by directly measuring current at 2,700 m must involve

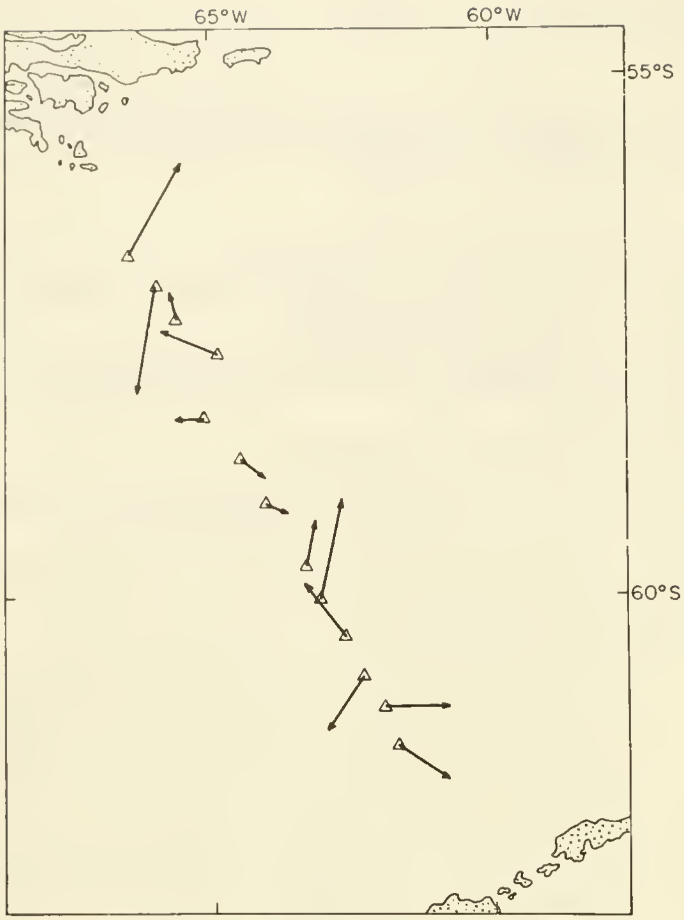

Figure 15.—Fourteen-day averaged currents across Drake Passage at 2,750-m depth, March 1–14, 1975.

Recovering vertical current meter (VCM) aboard RV THOMPSON, *March 1976. The VCM is a modified Swallow float. It floats at a given pressure surface. As it moves up and down through the water or as water flows vertically past it, the impeller spins and records the water movement*

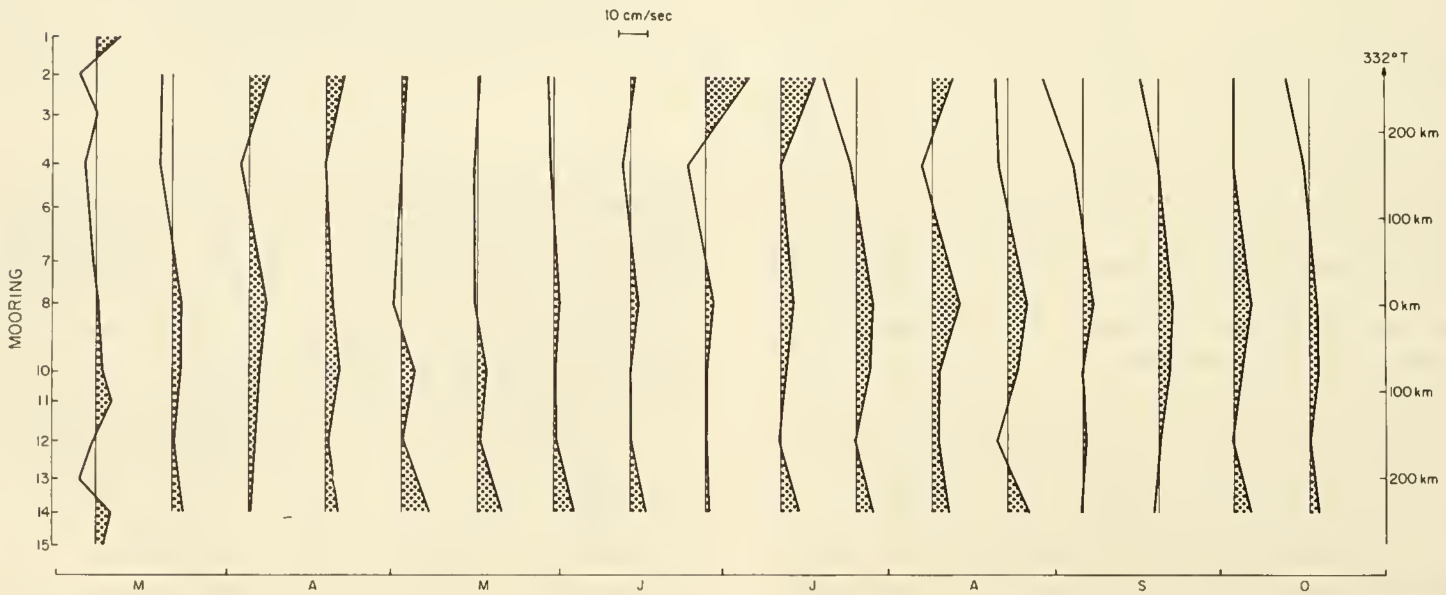

Figure 16.—Fourteen-day averages of down-channel (62°T) velocity, March to October 1975.

a large number of measurements. On the basis of our estimate of spatial variability, 23 current meters would be required to estimate a spatially-averaged current within ± 1 cm/sec, equal to a transport within ± 25 Sv. It is concluded that an array of horizontally-integrating measurements, such as pressure or sea-level measurements on each side of the passage, is the only feasible method of long-term monitoring of the variations in transport of the Antarctic Circumpolar Current through the Drake Passage.

The 3-week average speeds from the array of 15 current meter moorings discussed above were used in conjunction with geostrophic calculations to estimate the short-term transport of the Antarctic Circumpolar Current. Five closely spaced hydrographic sections were made across the Drake Passage during this 3-week period in March 1975. The geostrophic transport relative to 3,000 decibars averaged 95 Sv for the five transects; this is consistent with estimates based on previous hydrographic measurements. Referencing the geostrophic transport to the current meter measurements gave an adjusted transport of 124 Sv to the east.

During F DRAKE 76, the small-scale structure of the polar front was studied in the Drake Passage. Two ships, the RV Thompson (University of Washington) and the Chilean naval vessel AGS Yelcho, combined efforts in the program that took place during the onset of the austral autumn. Described here is the evolution of the polar front between February 29 and April 5, 1976.

The polar front, in reality a transition zone between antarctic and subantarctic water masses, is most clearly revealed in vertical sections of temperature as shown in fig. 17. South of the frontal zone is a temperature minimum layer between 100 and 300 m. This feature is insulated from seasonal heating at the surface. Within the frontal zone, the minimum deepens abruptly and erodes, splitting into multiple extremes of interleaving antarctic/subantarctic waters. Although numerous definitions of the polar front have been suggested, the operational definition used here is the presence of a well-defined temperature minimum layer as delineated by the 2°C isotherm. The selection of the 2°C isotherm is somewhat arbitrary, but it does provide a convenient, consistent, and objective method of defining the position of the southern edge of the frontal zone.

Synoptic maps of the front were produced with the combined data from the two vessels. Although some artistry is involved in smoothing the observations, the horizontal density of measurements is sufficient to resolve the structure. Figure 18, a composite of these maps, indicates that between March 10 and 24 a large meander developed in the polar front. This was verified by thermistor chain measurements (position shown in fig. 18) from a subsurface mooring in the vicinity and by the distribution of surface properties (not shown). The meander subsequently pinched off a ring of between 60 to 80 km diameter, which then drifted to the NE at a speed of about 10 cm s^{-1}. The ring formation process is reminiscent of that observed in western boundary currents such as the Gulf Stream. Continuous profiles of temperature and salinity show that the antarctic water types inside the ring penetrate to a depth of 2,500 m, suggesting that much of the water column is involved.

Subsurface neutrally buoyant floats equipped with fins to react to vertical water motion, were tracked acoustically from the RV Thompson during the period of the ring formation. The track of these floats indicates that three of the four vertical current meters (VCM) were entrapped in the ring. Horizontal velocities of the floats were 30 to 40 cm s^{-1}.

This process can potentially transport large amounts of antarctic or subantarctic water across the front and may be fundamental to the understanding of heat and salt transfers toward the polar region. If the cold ring is reabsorbed into the circumpolar current, the net transfer of properties will be less than if the ring were to remain detached, slowly decaying with time. Downstream of the Drake Passage, the circumpolar current system is highly constrained by the Scotia Ridge, which has only two large openings with a sill depth >2.5 km. It is interesting to speculate upon the fate of this cold water ring when it drifts into this rather formidable topography.

During January and February of 1977, the RV Melville recovered the array of tide gauges, deep-sea pressure gauges, and current/temperature/pressure recorders that were deployed across Drake Passage during February 1976 as a part of F DRAKE 76. While in this region, the Melville deployed another year-long instrument array, and short-term experiments and supporting hydrographic/STD work was done. This field operation was called F DRAKE 77.

As the final phase of F DRAKE, a 1-year clustered array was deployed in January and February 1977 (figs 19 and 20) to meet the following objectives:

1. Determine the spatial variability of the currents with meter spacings from 15 km to 60 km.

2. Describe the movements of sharp bands of currents through the cluster and to identify rings formed at the Polar Front Zone.

3. Allow continuous geostrophic comparisons and to compare local changes of temperature with horizontal advection of temperature to understand the importance of nonlinear effects.

4. Extend time series of currents, temperatures, and pressures for a third year.

The CTD/STD program included measurements of temperatures, salinities, and dissolved oxygen concentrations using bottles on the CTD wire and a rosette sampler. The objectives for making these measurements are to:

1. Define the density field in the region of the moored cluster and at the pressure recorders at the time of deployment of the 1977 array.

2. Make a section along the line of the 1976 moored array to obtain another short-term estimate of transport through the Drake Passage.

3. Obtain clusters of hydrographic stations at a series of spacings around a 1977 mooring heavily instrumented in the vertical for use in comparing directly measured with calculated vertical shears.

Bottom pressure measurements at 500 m depth on either side of the Drake Passage will be continued to monitor temporal fluctuations in pressure difference across the Passage. It is expected that this program of simultaneous pressure meas-

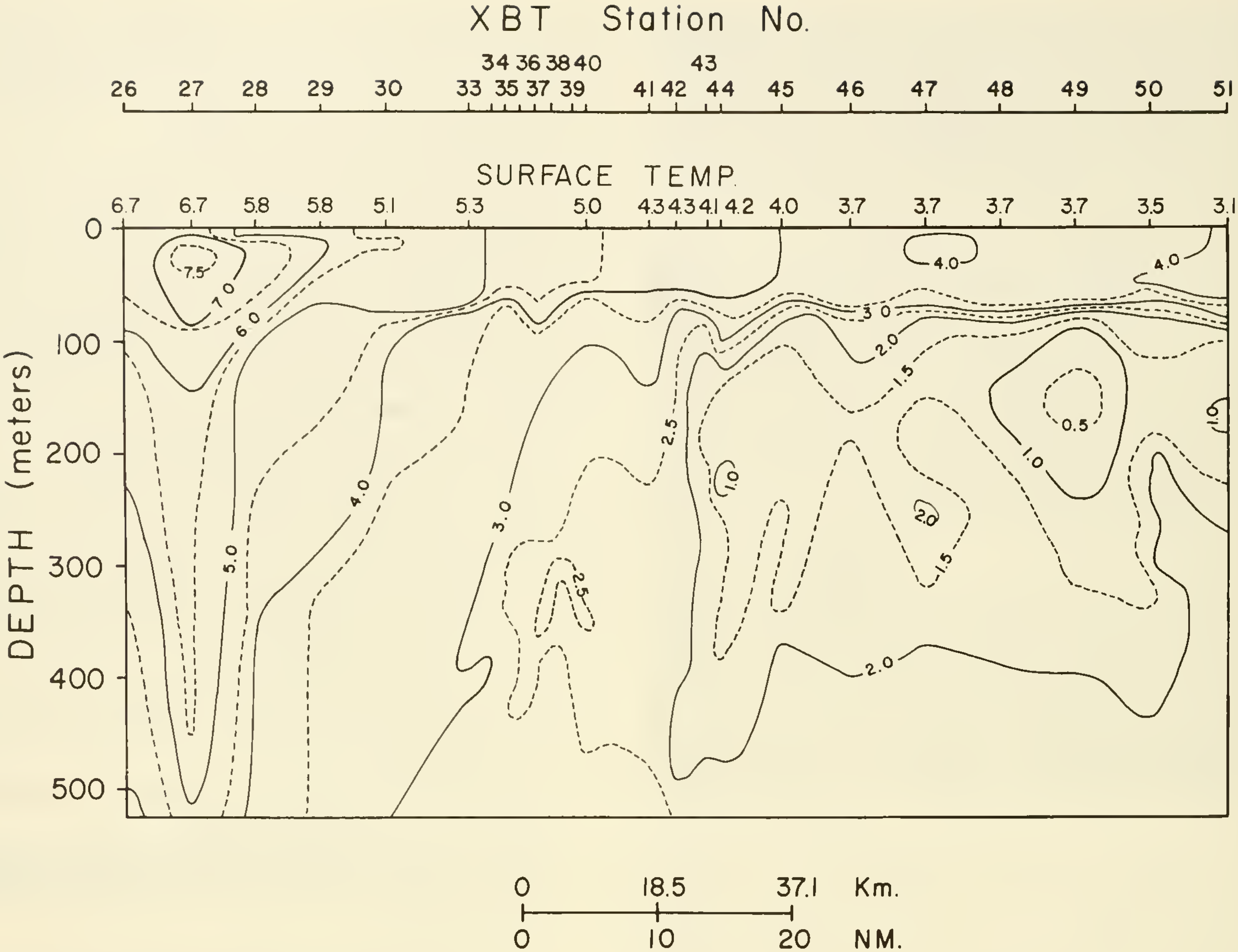

Figure 17.—Expendable bathythermograph (XBT) section across the polar front. Contours are in °C. Starting and ending positions for section are 56°44.8′S, 65°33.4′W and 59°02.0′S, 63°02.5′W.

urements will be an efficient means of monitoring geostrophic fluctuations of the mean down-channel flow at 500 m depth. The existing hydrographic data from Drake Passage show the relative baroclinic transports to be nearly constant. To the extent that this is true, the fluctuations in total transport through the Drake Passage will be measured by the pressure gauges.

ISOS includes individual theoretical studies and regular meetings of a panel on theoretical studies. The studies emphasize circumpolar current dynamics. Included are laboratory investigations, an analytical study of topographically-induced jets in a zonal channel, and analytical studies of the interaction of bottom topography and circumpolar current. Another ISOS project provides for the publication of a Southern Ocean Atlas. Completion of the atlas is expected in 1978.

An ISOS project initiated in 1976 obtains XBT sections from supply and research vessels that cross the circumpolar current (fig. 21). These data, in conjunction with satellite observations, will allow investigation of the temporal and spatial changes of the Polar Front.

From January to February 1977, a collaborative effort with the U.S.S.R. to obtain hydrographic and current data along 130°E from the Soviet R/V Professor Zubov was carried out. Unusually bad weather prevented accomplishment of planned objectives; for example, of the 24 hydrographic stations planned, only 8 were obtained. A number of XBT surveys were performed that documented the existence of a cold-core eddy at 132°E, 51°S.

In 1978, a cluster of current meters will be deployed in the Circumpolar Current to the east of Campbell Plateau at about 54°S, 174°E. Upstream pressure fluctuations across Macquarie Ridge will be monitored with pressure gauges. The moored instruments will be retrieved in austral winter/spring; and at that time, the formation of subantarctic mode water will be studied. These studies will be carried out in cooperation with New Zealand and Australian oceanographers.

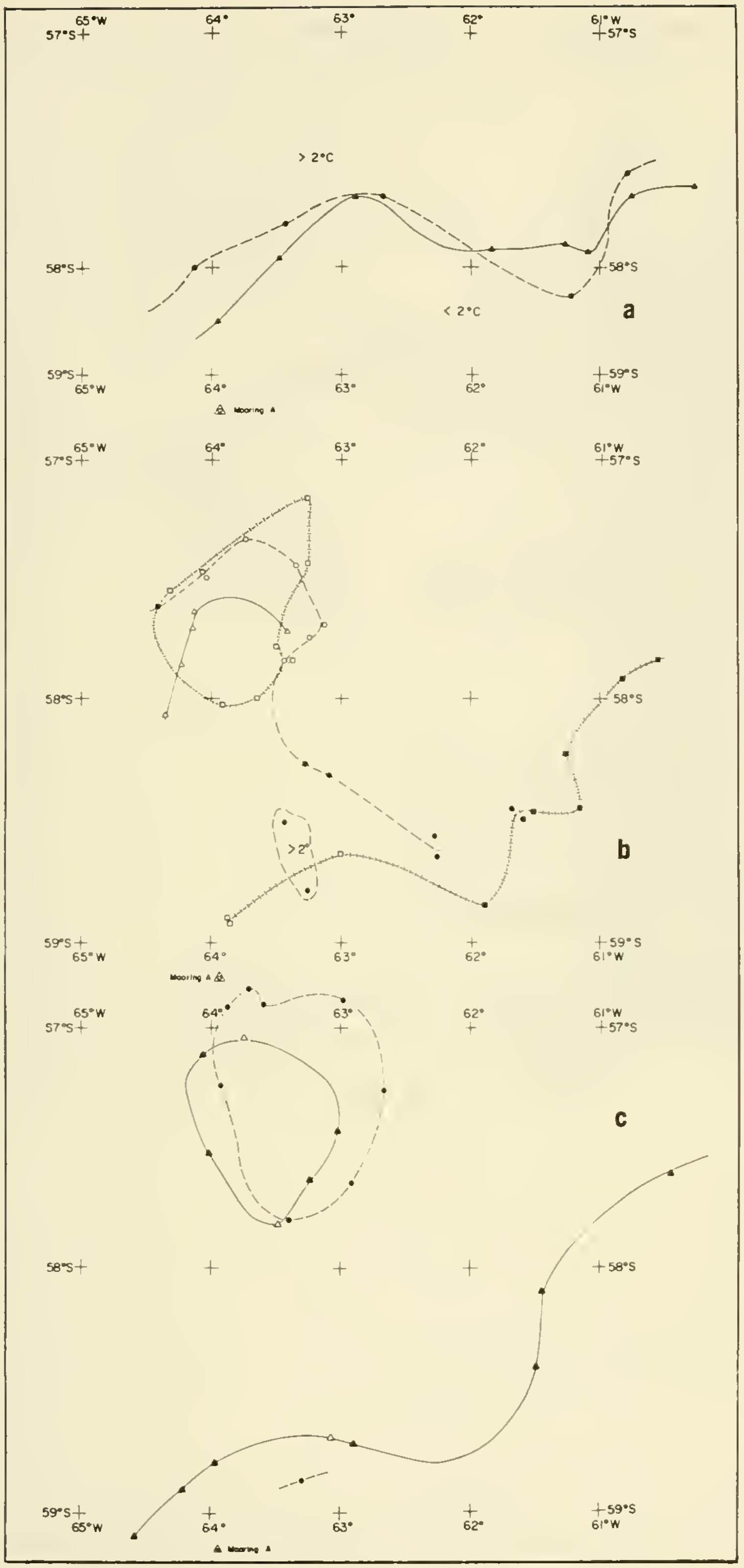

Figure 18.—Evolution of the polar front. Shown contoured is the boundary between antarctic waters and the interleaving regime of the frontal zone. Times are coordinated universal (CUT). a. February 29, 0130 to March 5, 1830, solid line; March 8, 1330 to March 9, 1540, dashed line. b. March 16, 0000 to March 20, 2359 solid line; March 21, 0000 to March 26, 2359 dashed line; March 27, 0000 to March 30, 2359, plus line. c. March 31, 0000 to April 3, 2359 solid line. April 4, 0230 to April 5, 1315 dashed line. Solid symbols represent observations from the YELCHO, open from the THOMPSON.

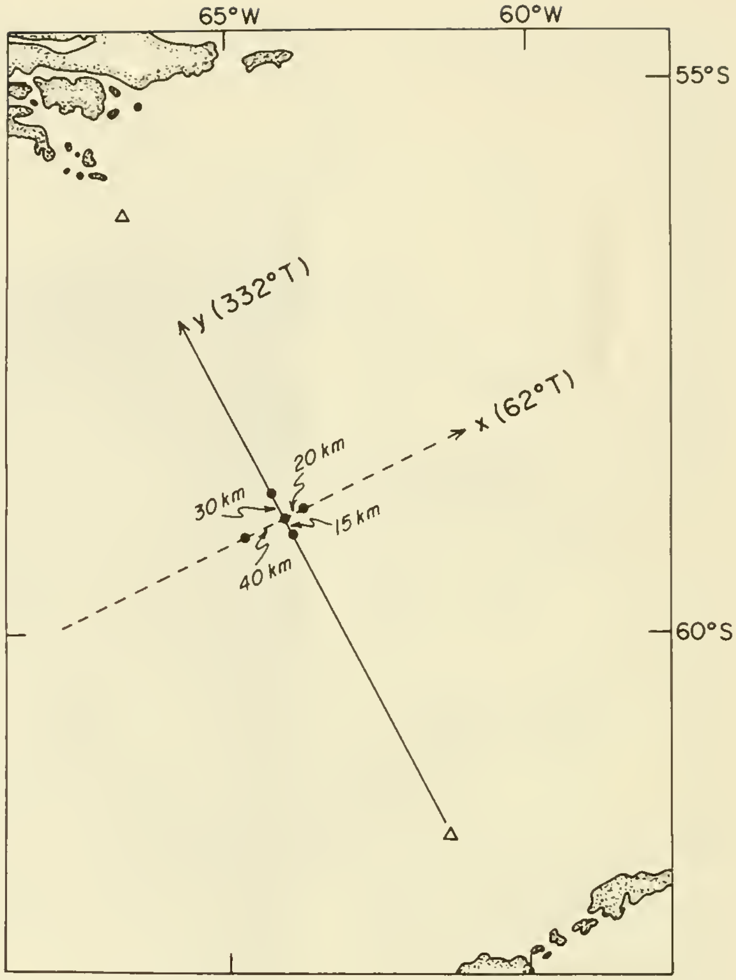

Figure 19.—Instrument array deployed in Drake Passage in February 1977. Current meter location, (●); pressure recorder moorings (∆); X and Y, lines of bearing from true north for aligning instruments.

In 1979, a S DRAKE (Second Dynamic Response and Kinematics Experiment) project is planned.

ISOS Data

ISOS data are available from NODC as follows:

NODC Accession No.: 77–0058
Organization: Texas A & M University
Investigator: S. Patterson
Grant No.: NSF/OCE74–14941 AO2
Project: F DRAKE 76
Data: 571 Surface Temperatures, salinities, and silicates taken aboard A.G.S. YELCHO cruises F DRAKE leg 1, February 27, 1976 to March 13, 1976 and leg 2, March 22, 1976 to April 8, 1976 in Drake Passage. NOTE: 571 XBT logs and strip charts were sent to FNWC, Monterey, for digitizing.

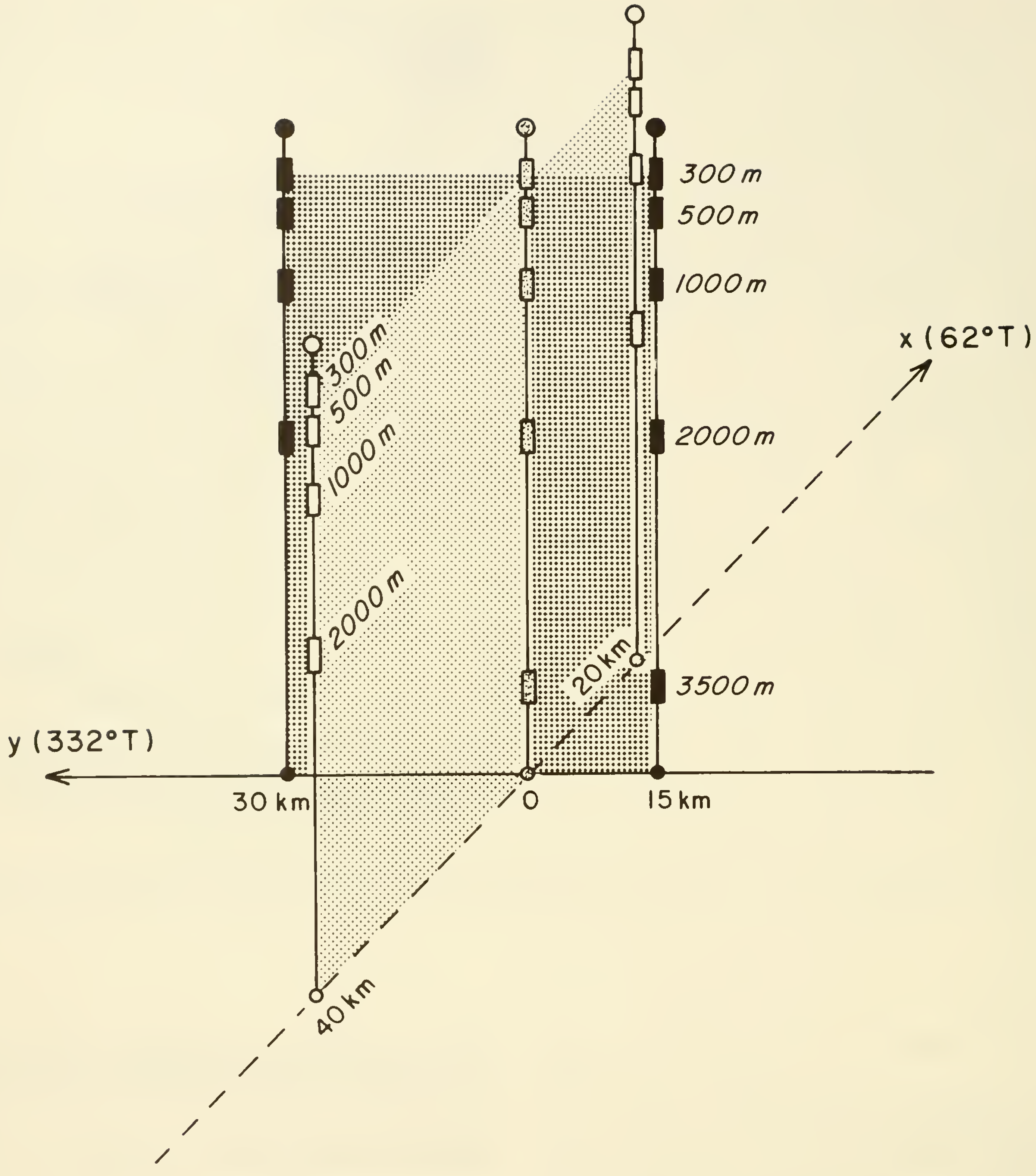

Figure 20.—Cluster array deployed in center of Drake Passage during F DRAKE 77.

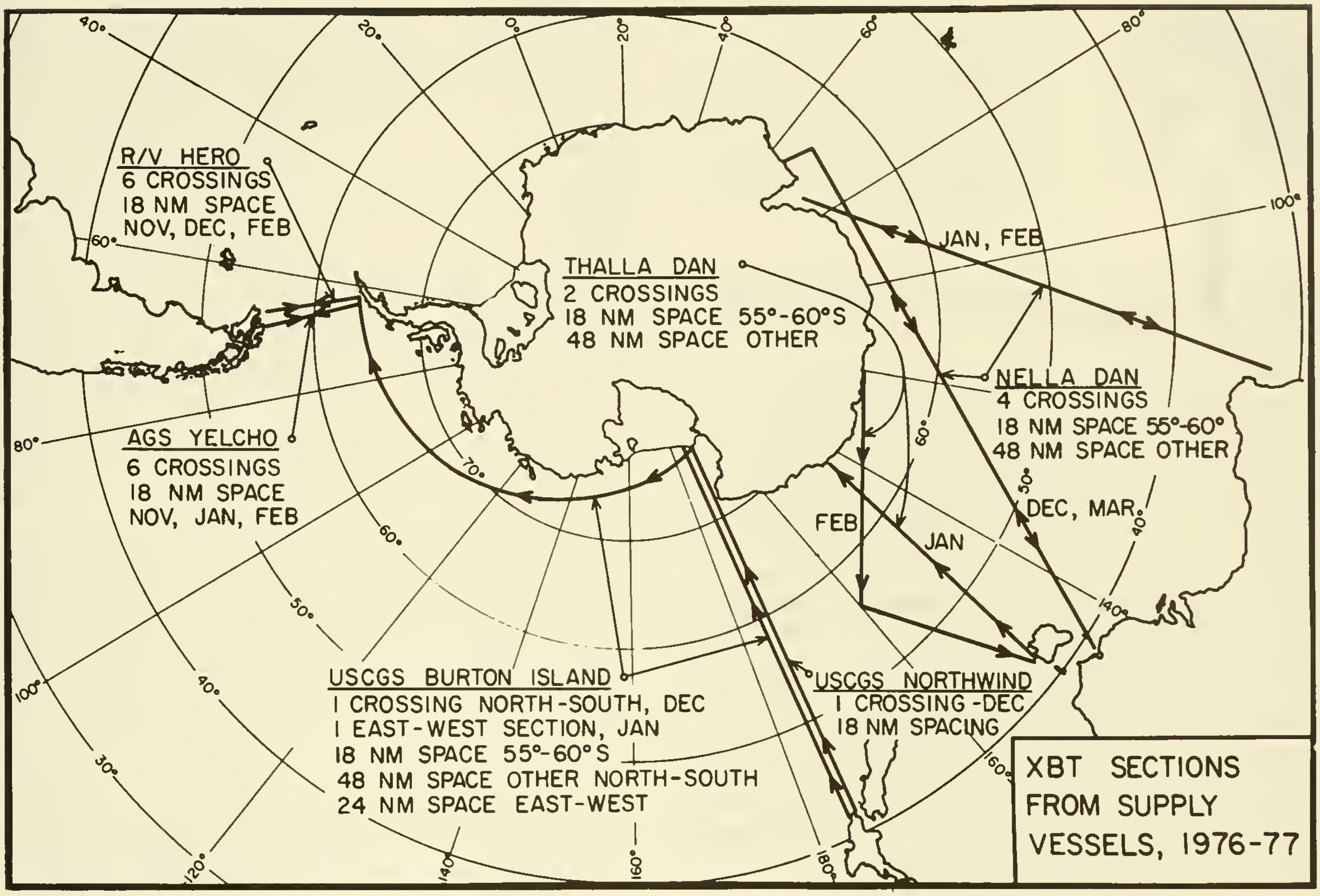

Figure 21.—XBT sections from supply vessels, 1976–77.

NODC Accession No.: 76–1927
Organization: Lamont-Doherty Geological Observatory
Investigator: A. Gordon
Grant No.: NSF/IDO74–15062
Project: F DRAKE 75
Data: 57 STD's on binary coded magnetic tape and bottle data on punched cards. Data was taken aboard R/V Conrad cruise 18, leg 1, February 2, 1975 to March 12, 1975 in the Drake Passage.

NODC Accession No.: 76–1512
Organization: Lamont-Doherty Geological Observatory
Investigator: A. Gordon
Grant No.: NSF/IDO74–15062
Project: F DRAKE 75
Data: 182 XBT's on binary coded magnetic tape taken aboard RV Conrad Cruise 18–01 February 2, 1975 to March 12, 1975 in the Drake Passage.

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Climate: Long-Range Investigation, Mapping, and Prediction (CLIMAP) Study

CLIMAP research is designed to describe and explain the major changes in global climate that have occurred in the past million years. These changes involve transitions between two partly stable states of global climate—ice ages and temperate periods. The fundamental objective is to improve our understanding of the physical mechanisms that cause these major variations in the atmosphere, ocean, and ice sheets. Because these changes have simpler geographic patterns and occur more slowly than climatic changes taking place on a year-to-year or decade-to-decade scale, they are in many ways easier to understand than the higher-frequency events. CLIMAP's central strategy is to view the geological record of the ice-age cycle as a huge, natural experiment to gain new climatic insights. These insights will help improve our ability to understand and forecast the economically important variations in climate that occur on human time scales. CLIMAP studies are jointly funded by NSF's Office of Climate Dynamics and Office for the IDOE. CLIMAP scientists are listed in table 12 and CLIMAP task groups in table 13.

A unique aspect of the CLIMAP study is that analyses of deep-sea sediments are used as the primary source of data. Deep-sea sediments are particularly useful as indicators of past climatic conditions for a variety of reasons. 1) They are not geographically restricted, and their global extent adds to their value as climatic indicators because the interchange between the ocean and the atmosphere plays a dominant role in climatic variations. 2) Deep-sea sediments accumulate at a relatively constant and continuous rate that is uninterrupted for perhaps hundreds of thousands of years. 3) The chemical, physical, and biological characteristics leave a permanent record of many aspects of the ocean, including the temperature and circulation pattern of the surface waters, the chemical nature of the bottom waters, and the extent of sea ice. In addition, isotopic studies of marine sediments make it possible to calculate historical changes in the volume of terrestrial ice sheets. Each sediment core is thus a multipurpose recorder monitoring past climatic changes.

Modeling of Ice Age Climate. One recent advance in CLIMAP research is the publication of a numerical model of the global atmosphere at the maximum extent of the last ice age, 18,000 years ago (fig. 22). This work is part of a larger program directed to reconstruct the geographic pattern of selected past climatic states—and to learn from these reconstructions how winds and the ocean currents balance the Earth's radiation budgets during climatic regimes quite different from today. The results shown in figure 22 were obtained by CLIMAP corresponding member W. L. Gates as follows: CLIMAP paleo-oceanographers first assembled synoptic records of the Earth's surface 18,000 years ago (fig. 23). These records include the extent and elevation of the ice sheets, the extent of sea ice, the temperature of the sea surface, and the albedo (reflectivity) of the land surface. This information is assembled and used as the set of boundary conditions for running a numerical model of the atmosphere. The surface air temperatures (fig. 22) and other properties of the ice age atmosphere are then calculated by the model. When averaged globally, and compared to temperatures calculated for the climate today, the mean air temperature decrease during the ice age was only 5°C. This result is one of the most important CLIMAP contributions to date. For the first time, we have an accurate estimate of the magnitude of the largest climatic change ever to occur during the past million years. Thus, we have a basis for judging the impact of any change in future climate that might occur either naturally or as the result of man's activities.

Solar Control of Climate. Another important advance in recent CLIMAP research is the publication of evidence that changes in the geometry of the Earth's orbit are a major cause of the ice ages. This theory, which was developed originally a century ago and has come to be known as the Milankovich theory, assumes that ice ages are caused by changes in the seasonal and latitudinal distribution of solar energy that must result when the geometry of the Earth's solar orbit changes (fig. 24).

Three periodic variations in the orbit occur as a result of changes in the position of planets in the solar system—variations in the eccentricity of the orbit, with an average period of about 100,000 years; in the tilt of the Earth's axis with a period of about 41,000 years; and a 22,000-year cycle in the position of the orbital path at which a given season occurs. According to a modified version of the Milankovich theory, each of these periodicities should be found in climatic records—if, in fact, the orbital changes are the fundamental cause of the ice ages. CLIMAP researchers assembled long climatic records from two deep-sea cores from the southern Indian Ocean, and discovered climatic periodicities so close to those predicted that the Milankovich theory is confirmed as the primary cause of the ice age cycle. The effect of the longest cycle is schematically shown in figure 25.

Other Accomplishments. Other accomplishments of CLIMAP during the past year include:

1. An interactive system of computer programs called the CLIMAP Update System has been designed to store paleo-oceanographic data. Over 11,000 carbonate, 4,000 isotope, and 140 radioisotope analyses will soon be added to the CLIMAP data file presently archived with EDS' National Geophysical and Solar-Terrestrial Data Center (NGSDC) in Boulder, Colorado.
2. A volume of 17 scientific papers published in 1976 reflects the multi-disciplinary efforts of the CLIMAP project. (Geographical Society of America Memoir 145, edited by R. M. Cline and J. D. Hays, *Investigation of Late Quaternary Paleo-oceanography and Paleoclimatology,* x + 446 pages, 245 figures, 66 tables, 26 appendices on three 98-frame microfiche for use on 24x readers.)
3. Studies of the movement of the North Atlantic Polar Front during the last major climatic cycle (127,000 to 12,000

Table 12.—CLIMAP Scientists

Executive Committee

R. Cline, Columbia University (Administrator)	A. McIntyre, Columbia University
G. Denton, University of Maine	T. Moore, University of Rhode Island
J. Hays, Columbia University	W. Prell, Brown University
R. Heath, University of Rhode Island	W. Ruddiman, Columbia University
J. Imbrie, Brown University	J. Thiede, Oregon State University

Senior Scientific Investigators

Brown University: W. Hutson, N. Kipp, R. Matthews, T. Webb, D. Williams
Columbia University: A. Be, P. Biscaye, W. Broecker, L. Burckle, K. Geitzenauer, V. Kolla, G. Kukla, Y. H. Li, B. Molfino, N. Opdyke, T. Saito, S. Streeter, P. Thompson
University of Maine: T. Hughes, W. Karlen, T. Kellogg
Oregon State University: L. Hogan
Princeton University: H. Sachs
University of Rhode Island: P. Dauphin

National Corresponding Members	International Corresponding Members
W. Balsam, Southampton College	B. Andersen, Univ. i Bergen
R. Barry, Univ. of Colorado	A. Berger, Univ. Cath. de Louvain
M. Bender, Univ. of Rhode Island	K. Bjørklund, Univ. i Bergen
M. Briskin, Univ. of Cincinnati	W. Dansgaard, Univ. of Copenhagen
K. Bryan, GFDL/NOAA	J. Duplessy, Centre des Faibles Radioactivites
H. Fritts, Univ. of Arizona	H. Lamb, Univ. of East Anglia
J. Gardner, USGS	J. Lozano, Univ. Nacional de Colombia
W. Gates, RAND Corporation	B. Luz, Hebrew Univ. of Jerusalem
L. Heusser, Tuxedo, NY	M. Sarnthein, Geol. Palaont. Inst. Kiel
J. Kennett, Univ. of Rhode Island	H. Schrader, Geol. Palaont. Inst., Kiel
R. Ku, Univ. of Southern California	N. Shackleton, Univ. of Cambridge
J. Kutzbach, Univ. of Wisconsin	E. Siebold, Geol. Palaont. Inst., Kiel
S. Manabe, GFDL/NOAA	T. van der Hammen, Univ. van Amsterdam
R. Newell, MIT	T. Wjimstra, Univ. van Amsterdam
D. Schnitker, Univ. of Maine	
H. Thierstein, Scripps Inst. of Oceanography	

years ago) indicate that at times the rate of movement can average in excess of 1 km/year over several thousand years. Thus, a major change in climate from a full-glacial state to an average interglacial configuration can occur in less than 3,000 years.

4. Polar studies in both hemispheres have shown that significant portions of ice age sheets were grounded below sea level. Compared to ice sheets on land, these marine ice sheets are relatively unstable. During the last ice age, the Antarctic ice sheet was considerably expanded from its present condition, mostly in the West Antarctic. Since then, the marine ice sheet there has receded slowly. During the last interglacial interval, about 125,000 years ago, this portion of the Antarctic ice sheet collapsed completely.

5. CLIMAP's synoptic reconstruction of the surface of the ice age world, 18,000 years ago, has been significantly improved by increasing the number and accuracy of the control points. In addition, reconstruction for average August and February conditions have been completed.

Future Activities. Future CLIMAP research plans include:

1. Numerical simulation of the ice age atmosphere by several general circulation models. Plans call for simulation experiments to be made by: W. L. Gates, Oregon State University; the Geophysical Fluid Dynamics Laboratory, Princeton; The National Center for Atmospheric Research, Boulder, Colorado; the Institute of Oceanology, Moscow; and members of the NORPAX project.

2. Detailed investigations of the dynamics of climate change immediately before, during, and after the last interglacial period before the present (circa 125,000 years ago).

3. Investigations of the frequencies of climatic changes as recorded in long deep-sea cores selected from all major oceans. Of particular interest in these studies will be a study of the timing of the response of various parts of the climate system during major regime changes: surface waters of the ocean, deep waters of the ocean, atmosphere, and ice sheets. In particular, it is important to find out what part of the global climate system responds first to changes in orbital geometry. This information will give valuable clues to the mechanism (now unknown) by which orbital variations influence climate.

Table 13.—CLIMAP Task Groups

Leaders	Tasks
L. Burckle	Diatoms
G. Denton	Ice Margin
J. Hays	Antarctic
J. Hays	Biostatigraphy
J. Hays	Radiolaria
L. Hogan	Volcanic Dating
T. Hughes	Ice Sheet Reconstruction
W. Hutson	Data Bank
J. Imbrie	18,000 B.P. Numerical Experiment
J. Imbrie and N. Pisias	Spectral Analysis
N. Kipp	Planktonic Foraminifera
N. Kipp and B. Molfino	South Atlantic
G. Kukla	Albedo
G. Kukla	Land-Sea Correlation
A. McIntyre	Coccoliths
A. McIntyre	Global Mapping
A. McIntyre	North Atlantic
T. Moore	Pacific
N. Opdyke	Paleomagnetics
W. Prell	Indian
W. Ruddiman	120,000 B.P. Experiment
N. Shackleton, R. Mathews, W. Broecker, and Y. H. Li	Oxygen Isotope
S. Streeter	Benthonic Foraminifera
J. Thiede	High Deposition Rate Core
J. Thiede	Mediterranean

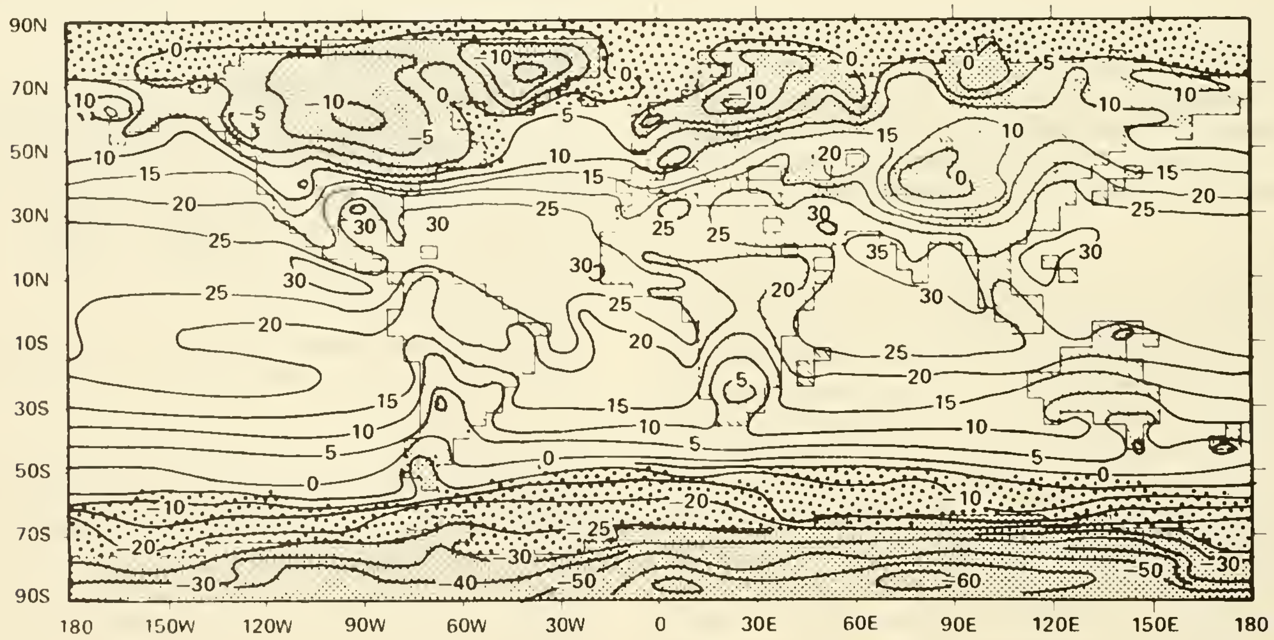

Figure 22.—The surface air temperature (°C) simulated for the iceage August by the atmospheric model. Large dots are for sea ice, small for ice sheets.

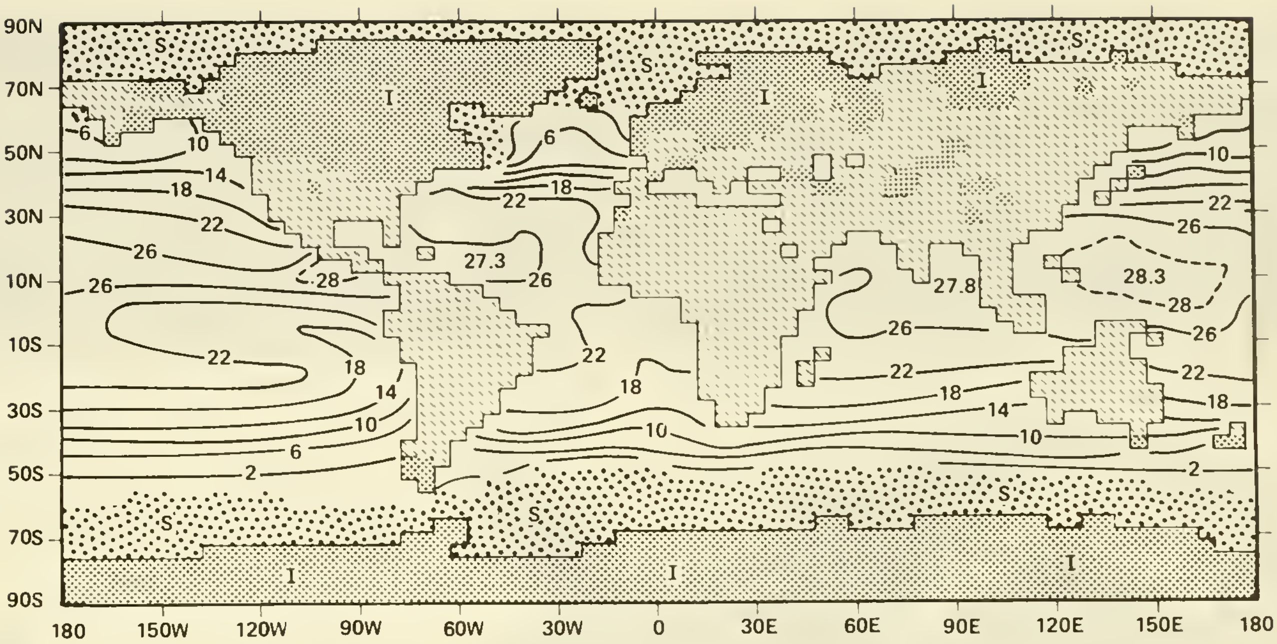

Figure 23.—Ice age (18,000 years ago) surface boundary conditions as assembled by CLIMAP for August. The sea-surface temperature is in degrees Celsius and the ice age land outline is that resolved on a global grid 4° in latitude by 5° longitude. The symbols "S" and "I" within the shaded areas denote the assigned locations of sea ice and ice sheets (including snow-covered land), respectively.

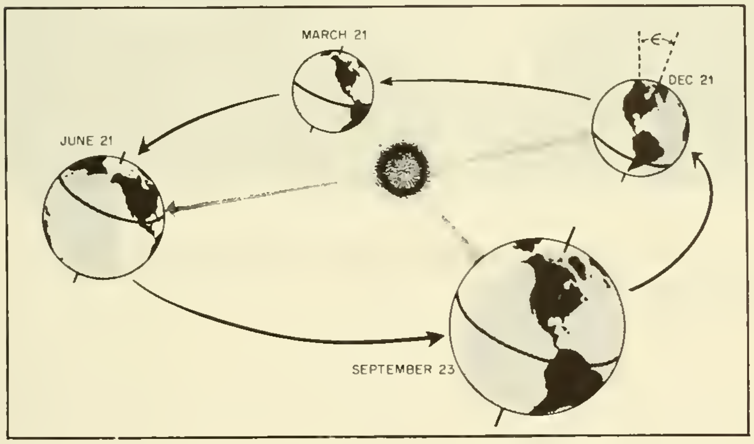

Figure 24.—The orbital diagram (G. Kukla, Lamont-Doherty Geological Observatory, Palisades, N.Y.) symbolizes research conclusions that variations in the Earth's orbit are the fundamental cause of the succession of late Pleistocene ice ages.

CLIMAP Data

CLIMAP Data are available from NGDSC as follows:

Paleontological and geochemical data are available for the 635 core locations indicated in figure 26. Paleontological data include counts of 51 species of diatoms, 44 species of planktonic foraminifera, 21 species of radiolaria, and 68 species of coccoliths. Geochemical data include percentages of opal, quartz, carbonate, and organic carbon. Percentages of opal and quartz were determined by X-ray diffraction, and carbon analyses were performed on a "Leco" Induction Furnace. A breakdown of the available data appears below:

Data Type	No. of Cores	No. of Analyses
Chemistry	219	1757
Coccoliths	96	886
Diatoms	43	43
Foraminifera	290	960
Radiolaria	173	624

In addition, each data record contains the following information:

1) Ship-cruise-core number
2) Latitude, longitude, and water depth
3) Core type, length, and sample depth within a core.

The CLIMAP data set is available on 7- or 9-track coded magnetic tape, at any compatible density, with a logical record length of 80 characters, blocked (5120 characters or less) or unblocked. Documentation and format of the data are provided in print form and also appear in text form at the beginning of the tape.

CLIMAP Bibliography

Papers cited below include only research directly funded by IDOE. Many significant contributions by national and international corresponding members not cited below were funded elsewhere, but were based substantially or in part on CLIMAP results.

Climatology

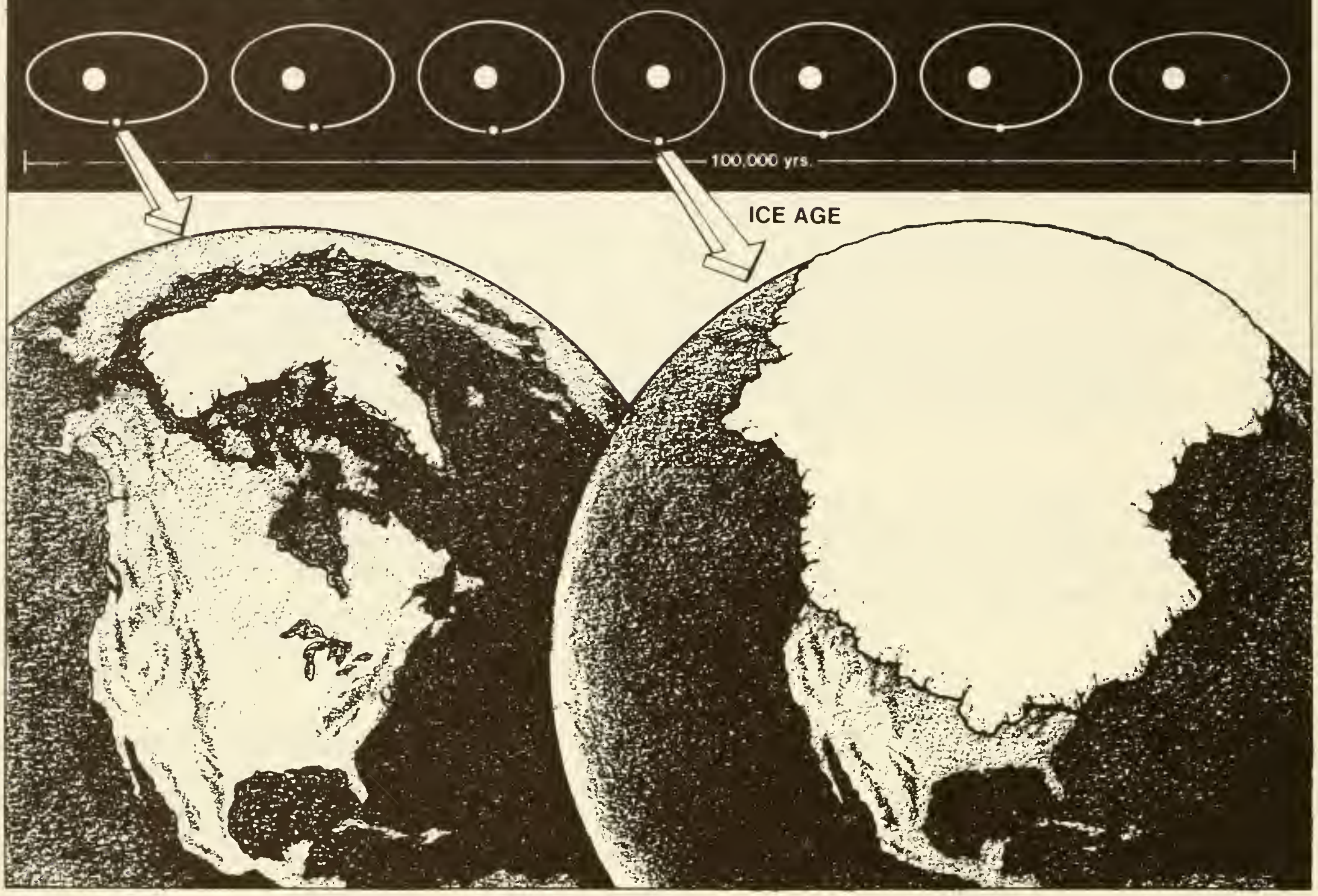

Figure 25.—At top, the Earth's changing orbit over a 100,000-year period. Ice sheet withdraws when orbit is eccentric, returns when it is circular. (Reprinted with permission of the ''New York Times''.)

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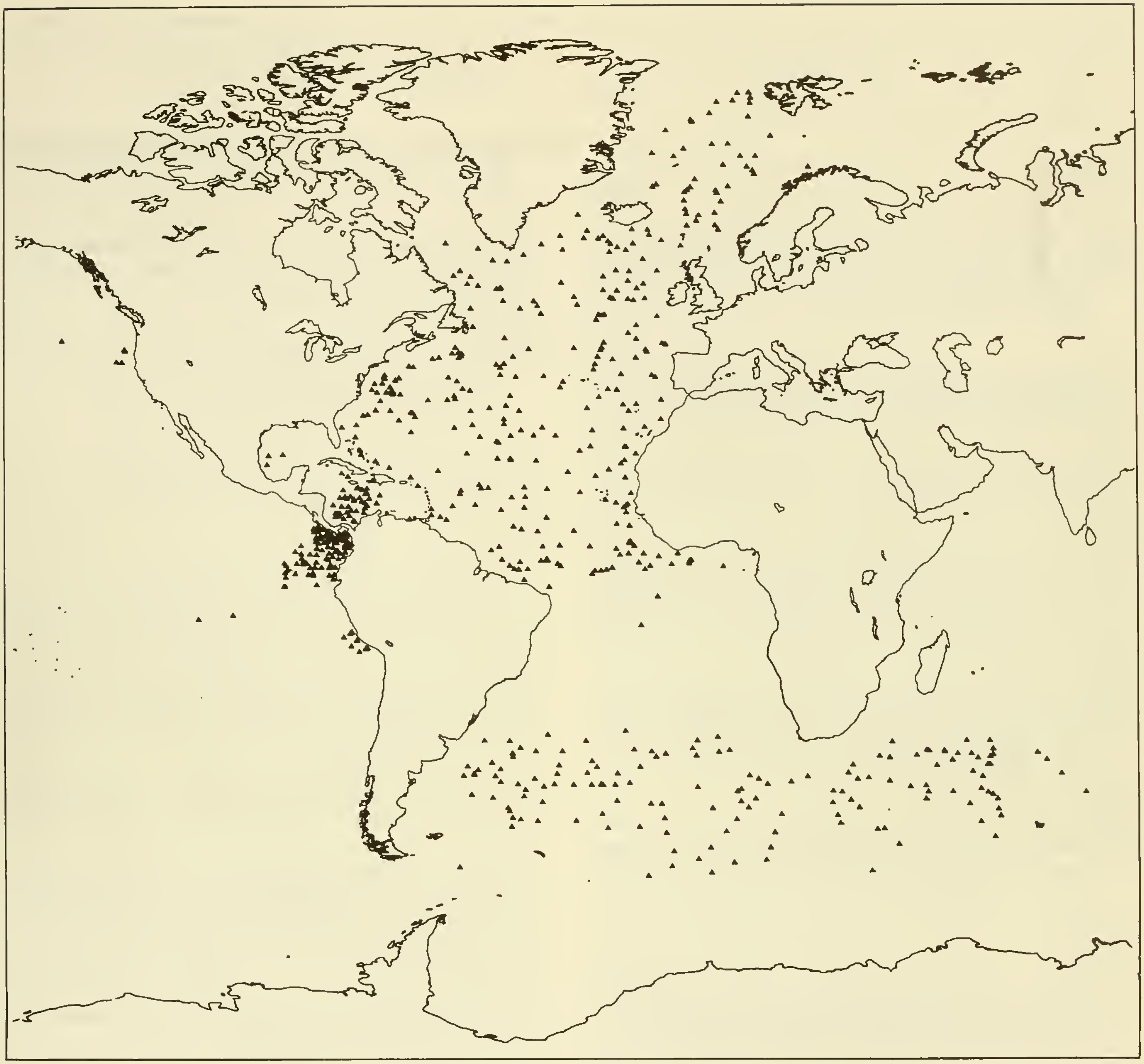

Figure 26.—CLIMAP core locations.

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Seabed Assessment Program

This program's objective is to investigate geological processes along continental margins, mid-ocean ridges, and deep-ocean basins. These processes form hydrocarbon and metallic ores and concentrate them into economically significant deposits. The projects supported by Seabed Assessment are broadly grouped as Continental Margin Studies, Plate Tectonics and Metallogenesis Studies, and the Manganese Nodule Study. Specifically, on going projects include:

1. African Atlantic Margin Study
2. Southwest Atlantic Continental Margin Study
3. Mid-Atlantic Ridge Study
4. Galapagos Spreading Center Study
5. Nazca Plate Study
6. Studies in East Asia Tectonics and Resources (SEA TAR)
7. Manganese Nodule Study

Projects of this large a scale require cooperation among several institutions and nations. The pattern commonly followed has three parts: synthesis of available data, field program for acquisition of new data, and finally, data synthesis and publication of results. The projects selected must have specific goals. They are designed to be completed in a specific time period ranging from 3 or 4 years to as long as 8 or 9 years. As will be indicated later, each phase of the project employs different techniques and instruments suitable to a logical development, usually with increasing size and sophistication. Moreover, more than one topic may be investigated in the same geographic location. For example, in the Nazca Plate and East Asia Projects, both continental margins and metallogenesis are subjects of inquiry. In the program to investigate the origin and distribution of manganese nodules, a single topic is investigated in a wide variety of ocean environments.

Continental Margin Studies

Continental margins are broadly divided between passive (pull-apart) and active (compressive) types. The South Atlantic Ocean is characterized by passive margins that have formed through geological times as Africa "pulls apart" from South America along the Mid-Ocean Ridge. Conversely, the Pacific Ocean "is closing" as the land masses around the circum-Pacific converge along its active margins. Studies along the south Atlantic margins were completed in 1976. In a series of recently published scientific papers, attention has been focused on the environments of sedimentary deposition and the structural features that controlled their distribution. Particular attention was given to identify the conditions favorable for the formation and entrapment of oil.

African Atlantic Margin

This comprehensive geophysical and geological survey from Capetown to Portugal fills a major gap in our world-wide knowledge of continental margins. Although specific problems remain to be investigated, a broad framework has now been established. K. O. Emery, who served as chief scientist on the project, and others have published major papers in the "Bulletin of the American Association of Petroleum Geologists."

Southwest Atlantic Continental Margin

A project along the coasts of Argentina and Brazil complementary to the African Atlantic Margins Study, was also completed in 1976. Groups of scientists from Lamont-Doherty Geological Observatory (L-DGO) gathered geological and geophysical data from the Scotia Arc, which lies between South America and Antarctica to the northeast coast of Brazil adjacent to the Caribbean. Geological field work was done on the islands of South Georgia and the southern-most Andes in cooperation with Antarctic investigations by United Kingdom scientists. Another group of scientific investigators from the Woods Hole Oceanographic Institution (WHOI) investigated the continental shelf of Brazil. Lamont, Woods Hole, and Brazilian scientists cooperated on a geological and geophysical study of the Amazon Cone. On a cooperative basis, Argentine, Brazil, and Chilean geologists participated in these cruises that took place along their respective continental margins.

The results of these investigations have been published in a series of papers. The large-scale geophysical and geological studies appear in *Geodynamics,* vol. 19, Continental Margins of the Atlantic Type, published as vol. 48 "1976 Annals of the Brazilian Academy of Sciences."

Continental Margin Data

Continental Margin Data are available from NGSDC as follows:

University of Texas at Galveston–J. Watkins, 420 n.m. of multi-channel (24 track) seismic data profiles on mylar. (See fig. 27.)

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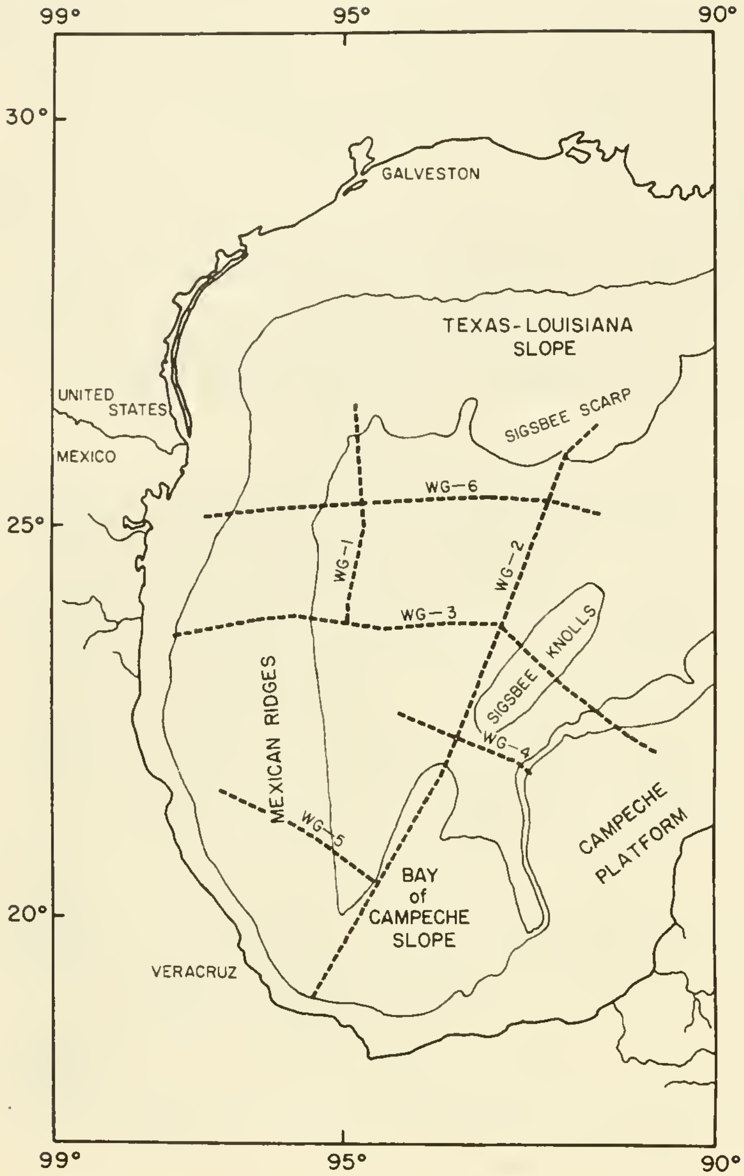

Figure 27.—Ship tracks for seismic data collected by University of Texas in Gulf of Mexico.

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Plate Tectonics and Metallogenesis Studies

Studies of the origin of ore deposits received new impetus when considered within the plate tectonic framework. The occurrences of ore deposits along past and present plate boundaries readily suggest some vital relationship.

The ore deposit itself and the terrain in which it is found however, is the end product of a long series of geological events, traces of which have often disappeared from the geological record. A series of investigations under the Seabed Assessment Program are designed to reconstruct the sequence of events that may have led to the concentration of some of the most widely used minerals (especially copper) and thereby provide economic geologists with some exploration tools in the search of new, vital resources. Processes creating new sea floor along the margins of spreading plates appear to generate one type of ore deposit, and those along the margins of converging plates appear to form another. Investigations of the Mid-Atlantic Ridge and the Galapagos Spreading Center focus on the sequence of rock units formed by the cooling crustal material and the role of sea floor hydrothermal circulation in the formation of metalliferous sediment deposits. The Nazca Plate Program and the East Asia Study help scientists relate the processes of subduction to the occurrences of mineral deposits in the adjacent overlying land masses.

Mid-Atlantic Ridge

The French-American Mid-Ocean Undersea Study (FAMOUS), a major international program, was the first attempt to make first hand observations of the geologic setting and processes of crustal formation along an active spreading center. Investigation of the Mid-Atlantic Ridge was carried out in the series of steps that culminated in 1974 with a deep submersible diving program. In addition to the manned submersible activities, Leg 37 (Deep Sea Drilling Project) drilled into the crustal material along the flank of the Ridge in the FAMOUS area. As part of the comprehensive investigation, deep holes were drilled in the Azores and suites of samples were dredged from the Romanche Fracture Zone.

The major results of Project FAMOUS are included in April and May 1977 volumes of the Bulletin of the Geological Society of America, vol. 88 nos. 4, 5.

Eighty samples of submarine basaltic lava were sampled from an 8 km segment of the floor and walls of the inner rift valley of the Mid-Atlantic Ridge during project Famous. The samples were collected from outcrops and talus slopes by the three submersibles: ALVIN, ARCHIMEDE, and CYANA at water depths of about 2,600 m.

The early formed mineral content of the pillow lavas' glassy margins enables classification of the rocks into 5 types: (1) olivine basalt, (2) picritic basalt, (3) plagioclase-olivine-pyroxene basalt, (4) aphyric basalt, and (5) plagioclase-rich basalt. Chemical and mineralogical study indicates that at least 4 types are directly interrelated and that types (1) and (2) are higher-temperature, primitive lavas and types (3) and (4) are lower-temperature, differentiated lavas derived from the primitive ones by crystal-liquid differentiation. The plagioclase-rich basalts also have a chemical composition of their glass comparable to that of the most differentiated basalts (types 3 and 4) but they differ in their greater amount of early formed plagioclase (12–35%).

In general, the mineralogical variation across the rift valley shows an asymmetrical distribution of the major basalt types. Despite the mineralogical diversity of the early formed crystals, the chemistry of the basalt glasses indicates a symmetrical and a gradual compositional change across the rift valley. Based primarily on their chemistry, the rock types 1 and 2 occupy an axial zone 1.1 km wide and make up the central volcanic hills. Differentiated lavas (types 3, 4) occupy the margins and walls of the inner rift valley and also occur near the center of the rift valley between the central hills.

FeO/MgO ratios of olivine and coexisting melt indicate that the average temperature of eruption was 40° C higher for the primitive melts (types 1 and 2). Aside from major elements trends, the higher temperature character of the primitive basalts is shown by their common content of chrome spinel.

The thickness of manganese oxide and palagonite on glassy lava provide an estimate of age. In a general fashion, the relative age of the various volcanic events follow the compositional zoning observed in the explored area. Most of the youngest samples are olivine basalt of the axial hills. Most older samples occur in the margins of the rift valley (West and N.E. part of explored area), but are significantly younger than the spreading age of the crust on which they are erupted. Intermediate lava types occur mainly east of the rift valley axis and in other areas where plagioclase—olivine—pyroxene basalt and aphyric basalt are present.

The above relations indicate that the diverse lava types were erupted from a shallow, zoned magma chamber from fissures distributed over the width of the inner rift valley and elongate parallel to it. Differentiation was accomplished by cooling and crystalization of plagioclase, olivine, and clinopyroxene toward the margins of the chamber. The centrally located hills were built by the piling up of frequent eruption of mainly primitive lavas, which also are the youngest flows. In contrast, smaller and less frequent eruptions of more differentiated lavas were exposed on both sides of the rift valley axis.

Galapagos Spreading Center

Scientists from Oregon State University, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, Massachusetts Institute of Technology, Stanford University, and the U.S. Geological Survey are participating in a program to study hydrothermal circulation processes on the Galapagos Spreading Center (fig. 28). The research submersible ALVIN will be used during February and March 1977 to do very detailed sampling of the hydrothermal water as it is discharged from the ocean crust. These detailed samples will enable the scientists to accurately determine the chemical composition, temperature, and rate of discharge of the hydrothermal fluids.

Previous oceanographic research in the area northeast of the Galapagos Islands had indicated that hydrothermal circulation was occurring along the Galapagos Spreading Center. In June and July of 1976, scientists in the IDOE sponsored program sampled bottom water temperatures and chemistry, and collected sediment samples in the area to pinpoint the most likely spots for hydrothermal activity. Two acoustic beacons were left on the seafloor to help scientists to relocate themselves during the diving program.

Directly over the zone of crustal generation along the spreading center scientists found bottom water temperature anomalies as high as 0.25°C. As normal seawater circulates down into the ocean crust in hydrothermal systems, it is gradually heated and driven upward. Where it discharges at the sea floor, it raises the temperature of near bottom water. During its transit, the seawater reacts chemically with the basalt of the ocean crust. Laboratory studies have shown that magnesium is removed from seawater; calcium and manganese are added to seawater during basalt-seawater reactions. In the area of high bottom water temperatures over the Galapagos spreading Center, the bottom water showed low concentrations of magnesium and high concentrations of calcium and manganese. This would be expected if a source of seawater that had reacted with basalt were present at the spreading center.

Thick crusts of manganese-rich material were recovered from the surface of small sediment mounds to the south of the spreading center. The mounds have apparently been the site of hydrothermal discharge, with the manganese precipitating as the hydrothermal fluids mix with seawater. On one of the mounds, the measured heat flow exceeded 30 h.f.u. Surprisingly, there were no recorded bottom water temperature anomalies over these mounds.

The use of the submersible will allow scientists to examine one of the remaining unanswered questions related to this process, the precise chemical composition and temperature of the fluid as it discharges at the sea floor. Samples obtained from a surface ship have undergone mixing between the hydrothermal fluids and bottom waters. Because there is no way to determine the amount of mixing that has occurred, there is no method of calculating the initial chemical compositions or temperature of the hydrothermal fluids. These two initial values are important in evaluating the significance of this process in modifying the chemical composition of seawater.

Nazca Plate

The Nazca Plate lies in the southeastern Pacific parallel to the western boundary of the metallogenic province of the Andes. This project was initiated in 1971 as a cooperative research effort between the University of Hawaii's Institute of Geophysics (HIG) and Oregon State University (OSU) with

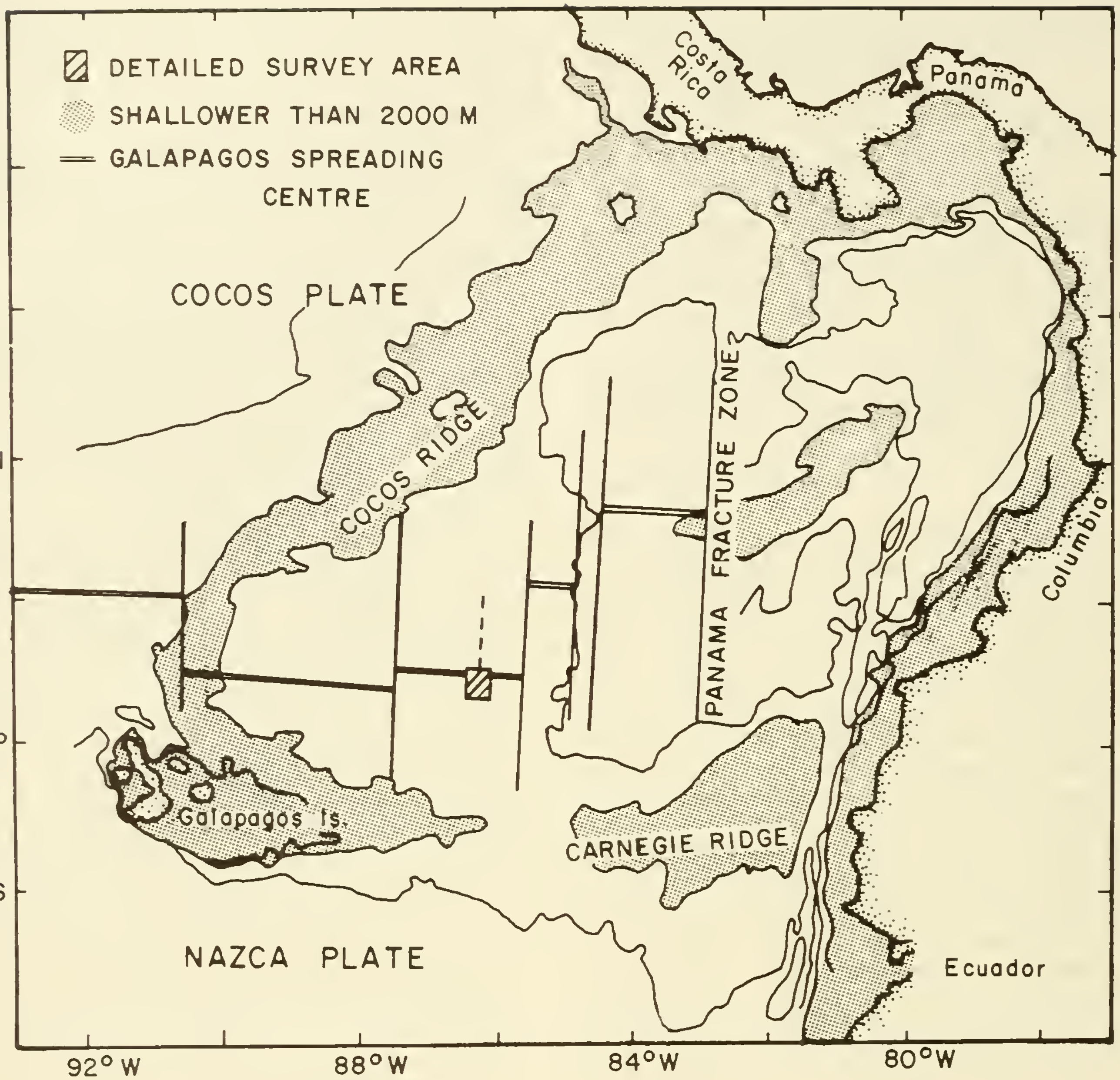

Figure 28.—Detailed survey area where ALVIN diving operations took place as part of the Galapagos Spreading Center program.

collaboration from scientists in Colombia, Ecuador, Peru, and Chile. A broad spectrum of geophysical and geochemical methods were used to investigate the possible connection between the oceanic plate tectonic cycle and the genesis of ore deposits in the Andes.

Several extensive and comprehensive research cruises were conducted during 1972–75. Data were collected primarily from the dynamic margins of the plate. The formation of new crustal material along the East Pacific Rise provided valuable insights in the processes of metalliferous sediment formation. Detailed investigations of the Peru-Chile Trench elucidated the processes of subduction. Analyses and interpretation of these data are scheduled for completion by 1978. Several articles have already appeared in scientific journals. A special synthesis volume is also being prepared to relate the research results to the metallogenesis theme. A series of geological, geophysical, and geochemical maps of the plate will accompany this volume.

Nazca Plate Bibliography

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Studies in East Asia Tectonics and Resources (SEATAR)

An international group of scientists have developed a cooperative program to implement the recommendations of a workshop on metallogenesis, hydrocarbons, and tectonic patterns in East Asia (Bangkok 1973). The workshop was convened by the Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas/Intergovernmental Oceanographic Commission (CCOP/IOC). Before initiating a large-scale field program, scientists at Lamont-Doherty Geological Observatory, Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, and Cornell University compiled and synthesized existing geophysical and bathymetric data. A bathymetric chart has been published. Extensive field work including land and marine studies was completed during 1976–77. Moreover, the presence of large research vessels in the area has encouraged other U.S. scientists to seek support from the Oceanography Program of NSF and ONR. The International Program of Ocean Drilling (IPOD) will use these data in selecting drilling sites for their Philippine Sea studies in 1977–78.

The SEATAR field projects collect both regional data based on a single geophysical or geochemical measurement and also concentrate on key transects using a large spectrum of these techniques. A heat flow map is being prepared by S. Uyeda (University of Tokyo) in cooperation with V. Vacquier (SIO). Both thermal gradient and conductivity measurements are taken on land and sea from shallow and deep wells. The Japanese team has provided training and equipment for heat flow measurements to scientists in the SEATAR countries. A valuable contribution to the heat flow map effort is the thermal gradient map prepared by SEAPEX (South-East Asia Petroleum Exploration), a geological professional society in Singapore.

The seismotectonic map is being prepared by Brian Isacks (Cornell). All major seismic events are being reanalyzed and plotted at precise subsurface locations to delineate the geometry and the rate of movement on the subducting plate.

The Landsat satellite imagery is under the guidance of the U.S. Geological Survey. A seminar workshop was held in Bangkok, January 1976 under S. J. Gawarecki (USGS). Reports of interpretation of Transects 1 (Thailand), 3 (Malaysia), 5 (Philippines), and 8 (Korea) have been completed.

New field programs are concentrated along three of the SEATAR transects. The Scripps field program is an extension of their work in the Andaman Sea (supported by the U.S. Office of Naval Research). J. Curray and his Scripps associates are completing a long-term investigation of the Bengal Deep-Sea Fan, the largest accumulation of turbidity current sediments in modern oceans. The investigation of this thick wedge of sediments in relation to their tectonic setting leads to an understanding of the processes of subduction and the formation of the sedimentary island arcs.

Dan Karig (Cornell) is studying this phenomenon along the islands off the southwest coast of Sumatra. Karig is documenting in detail, for the first time, the processes within the accretionary prism along converging continental margins on some of the offshore islands (especially Nias), where the phenomena of these processes can be observed in fine detail. Karig extended this investigation on the water covered areas by boarding the Scripps research vessel and collecting ocean bottom samples and correlating them with multichannel seismic data.

SIO and WHOI made two ship seismic refraction measurements in the Banda Sea as well as collecting other geophysical data bottom samples. The seismic refraction data should be especially valuable in defining the nature of the boundaries where the Pacific, Indonesian, and Australian plates collide and, in addition, increase understanding of the processes of crustal formation in the marginal seas that are considered to be different from those of major ocean basins.

On the Sunda and Banda Arc transects, well-documented, uncontaminated samples of sediments will be collected for Ian Kaplan (UCLA). Kaplan is investigating the role of earth-generated heat in the transformation of organic matter into hydrocarbons at plate margins.

The Indonesians have added a Java Transect to the originally designated Sumatra and Banda Arc Transects. Japanese scientists are cooperating with Indonesian scientists to complete geophysical (especially gravity) measurements on land to understand the deep structure of Java.

U.S. and Australian scientists have recently completed field work between northwest Australia and Timor. These data should provide new insights into the tectonic patterns and history of the northwest basin and the mechanism of forming the island arc group.

In the region north of the Banda Arc, Eli Silver (UCSC) and Russell Raitt (SIO) are investigating the Molucca Sea, an area of arc-arc collision and possible subduction of thick melange. Seismic refraction, reflection, and gravity data, as well as ocean bottom samples will be collected. Complementary studies on land will be done by J. Gill (UCSC) who will collect samples from volcanoes. The results of these two studies should provide criteria for recognizing zones of arc-arc collision in the geological column and the nature of the relationships between andesitic volcanism and subduction. Although these two studies are not supported by IDOE, the results bear on the understanding of the tectonic evolution of the area.

The Philippine Transect extends over both land and marine areas. The island of Luzon is rich in both chromite and copper gold deposits. The mode of formation of these ore deposits in the converging basins on both sides of the island is an unresolved problem. In 1976, a group of five U.S. and Philippine geologists visited key mining sites on Luzon and

collected suites of samples. Using petrological, geochemical, and isotope data, efforts will be made to determine age relationships, source of magma, and the geometry of hydrothermal circulation around the ore deposit.

Marine studies along the Philippine Transect at 18° N extend across the Philippine plate from the Mariana Trench to the island of Luzon. J. Hawkins (SIO) collected samples of volcanic rocks from the islands of Yap and Palau at the eastern edge of the plate where the processes of island-arc formation can be observed in an early state of formation before being complicated by the processes of volcanism. Scripps, Lamont, and the University of Hawaii took geophysical measurements to relate the characteristics of the Philippine plate to the complex geology of Luzon. These surveys will also serve for IPOD drilling. Several test holes along the transect are planned in 1977–78.

SEATAR Data

SEATAR data are available from NGSDC as follows:
Scripps Institution of Oceanography–J. Frazer, digital data files containing sediment descriptions, station locations, and bibliographic references for 9,100 samples from 800 stations.

Manganese Nodule Study

The IDOE Manganese Nodule Study was conceived during a workshop at Lamont-Doherty Geological Observatory in January 1972. A multi-institutional approach was recommended to solve the long-standing questions concerning the origin, distribution, and geochemistry of this unique marine resource. Proposed studies were organized into separate phases.

Phase I involved compiling existing manganese nodule data as a baseline for defining the future field work in the program. A series of technical reports and conference proceedings were published as a result of Phase I activities. These were reported in *IDOE Progress Report Volume 4,* April 1974 to April 1975. A project coordinator's office was also established during this interval.

Phase II of the study began in 1974 and was composed of a series of cruises in an area of the northern equatorial Pacific that contains extensive deposits of nodules enriched in copper and nickel. Recovered samples have been distributed to participating institutions for studies of the physical and chemical structure of nodules, chemistry of sediments and interstitial fluids, composition and structure of biogenic components, rate of nodule growth, and characteristics of environments in which nodules occur.

Perhaps the most significant aspect of the program during Phase II was the development, deployment, and recovery of a bottom ocean monitor (BOM) package. This package was deployed for a period of 4 months near 11° N, 140° W. It contained a camera, current meter, and nephelometer for measuring suspended sediment concentration in the near-bottom water. A preliminary analysis of the data reveals a noticeable variation in suspended material over relatively short periods. Abundant animal life is indicated in bottom photographs, but detailed analysis of time-lapse photographs is necessary to determine whether the organisms significantly disturb or move the nodules.

The third phase of the program, beginning in 1977, will concentrate on a detailed study of the influx, remobilization, and final disposition of transition metals supplied to the deep-sea floor of the central eastern Pacific. The ocean bottom monitoring package will be further developed to contain a number of passive and active experiments to measure in situ chemical fluxes between nodules and the surrounding sea-floor environment. During the remainder of phase III these instrument packages will be deployed at five sites in the eastern Pacific (fig. 29).

During 1976, the program surveyed two sites in the central Pacific (fig. 30) using the deep-tow system of Scripps Institution. The fine scale bathymetry, side-looking sonar, and photographic coverage, as well as the acoustic navigation provided by the deep tow allowed accurate sampling of nodules from the survey areas. Two bottom monitor packages were deployed in the station 20 area during August 1976 and will be recovered during late February 1977.

Manganese Nodule Data

Manganese Nodule data are available from NGSDC as follows:
Hawaii Institute of Geophysics. – J. Andrews, data report containing descriptions of 250 cores collected during RV Kana Keoki Cruise 1971.
Hawaii Institute of Geophysics – S. Margolis, magnetic tape containing 1,734 references to literature relating to manganese nodules for the period 1874–1975.
Scripps Institution of Oceanography – J. Greenslate, digital data and descriptive information for 196 core, grab, and dredge samples.

Manganese Nodule Bibliography

Andrews, J. E., E. Callender, C. J. Bowser, J. L. Mero, M. Gauthier, M. E. Meylan, J. D. Craig, K. Binder, P. Volk, A. Chave, and W. Bachman. 1974. Ferromanganese deposits of the ocean floor; Cruise Rep. MN–74–01 RV Moana Wave, Honolulu to San Diego, July 17–August 10, 1974. HIG–74–9, Hawaii Inst. Geophys., Univ. Hawaii, 194 p.

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Greenslate, J. 1976. The IDOE/NSF Manganese Nodule Project: a review of progress. MTS–IEEE Symp. Oceans–76 2D1–2D9.

BOTTOM OCEAN MONITOR *(BOM) ready for launching. Glass spheres in top of photo provide bouyancy for returning instrument to surface. Current meter hangs between spheres and sea-floor instrument package*

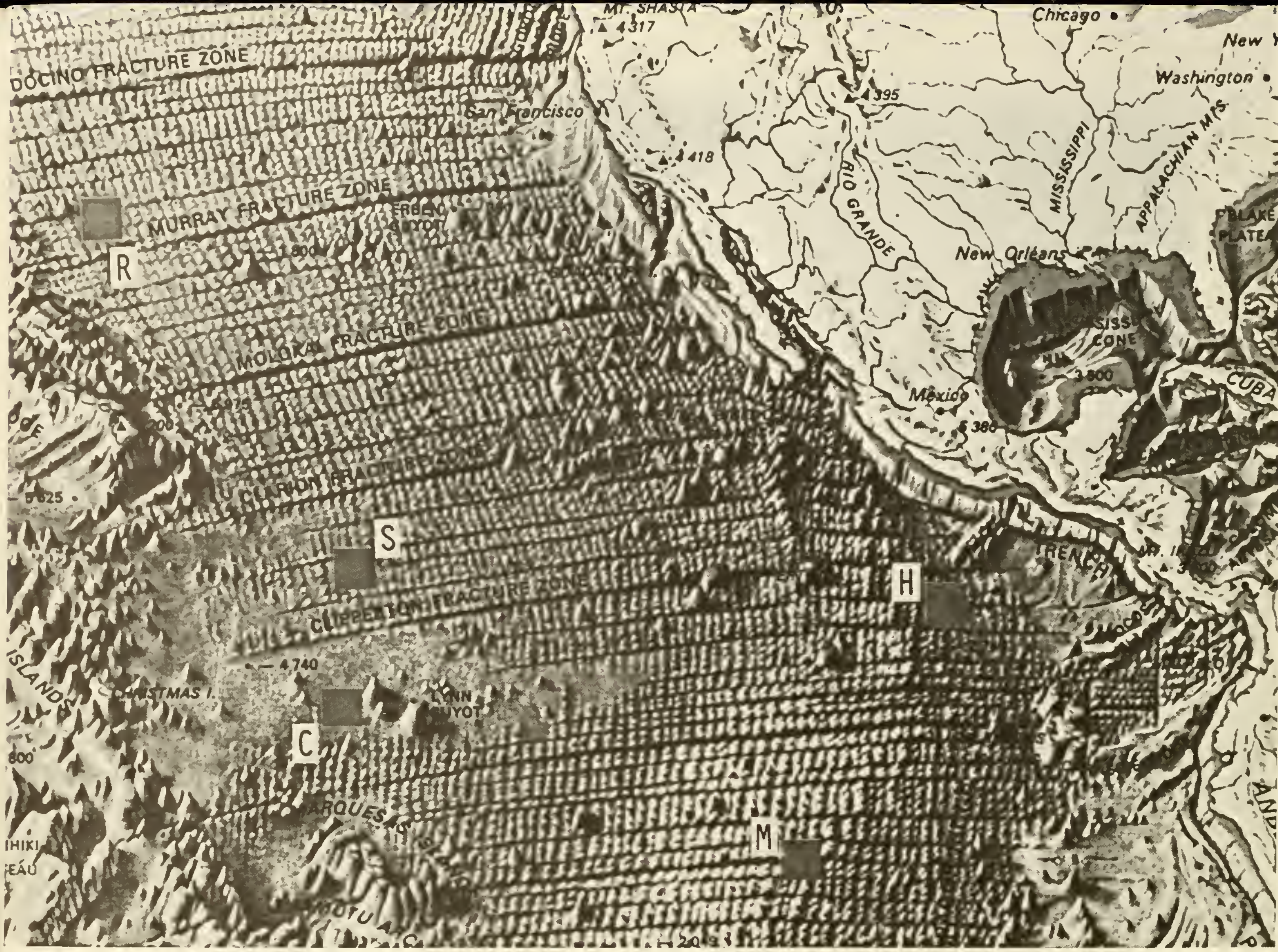

Figure 29.—Generalized topographic settings of proposed Bottom Ocean Monitor (BOM) survey areas.

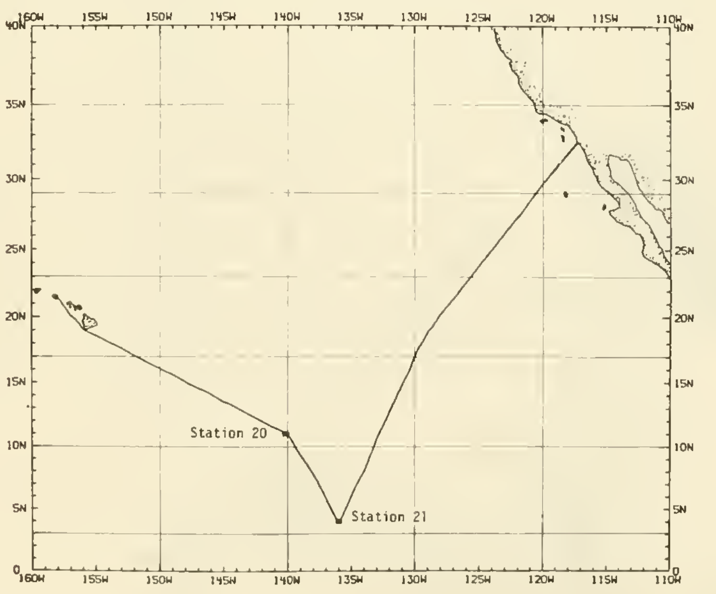

Figure 30.—Manganese Nodule Study track chart and station locations. Recorded underway were 3,378 miles of bathymetry and 3,288 miles of magnetics.

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Living Resources Program

The goal of this program is to provide scientific knowledge for improved management and use of the ocean's living resources. Emphasis is on interdisciplinary studies of the mechanisms that produce and sustain marine life. The program includes the Coastal Upwelling Ecosystems Analysis (CUEA) and Seagrass Ecosystem Study (SES) projects.

Coastal Upwelling Ecosystems Analysis (CUEA)

The long-term goal of the CUEA program is to understand coastal upwelling ecosystems well enough to predict their response to changes far enough in advance to be useful to mankind. This goal, when achieved, provides the basis for protecting the long-term productivity of fisheries in these ecosystems. The multidisciplinary CUEA projects are listed in table 14. To achieve its goal, CUEA has four objectives:

1. Describe and understand the mesoscale distributions that define coastal upwelling ecosystems in space and time including such variables as radiation, winds, currents, density, nutrients, phytoplankton, zooplankton, nekton, and benthos, as well as analyses of the spectral characteristics of each.

2. Understand the dynamic processes that affect the total behavior of these ecosystems, and to derive quantitative values of wind-induced upper oceanic circulation, mesoscale flow fields, uptake of nutrients by phytoplankton, and other processes that can limit grazing, predation, excretion, respiration, and remineralization.

3. Learn more about the physical, chemical, and biological interactions that increase the production of coastal upwelling ecosystems by an order of magnitude over that of open ocean areas.

4. Develop models that will simulate the Northwest African and Peruvian upwelling ecosystems, and which will provide the basis for predicting the response of these ecosystems to variabilities in scales and rates of processes, or to different fishery management strategies.

Six field programs are complete: MESCAL–I and II, CUE–I and II, and JOINT–I and II. MESCAL–I and II were primarily biological studies off the coast of Baja California during March 1972 and March and April 1973. CUE–I and II were physical oceanographic studies off the Oregon coast during April through October 1972 and the summer of 1973. JOINT–I was the first integrated biological and physical field study off the northwest coast of Africa during February through May 1974. JOINT–II was an intensive collaborative study of the Peruvian upwelling region ecosystem with a field phase from March 1976 to May 1977.

Most JOINT–II investigations were in an area about 100 by 100 km, centered at 15° S between Pisco and San Juan, Peru, during three intensive phases: March to May 1976 (MAM 76), July to November 1976 (JASON 76), and March to May 1977 (MAM 77). Observations were made using seven Canadian, West German, Peruvian, and United States research vessels, as well as aircraft, moored current meters, coastal meteorological stations, and satellites. The conceptual framework included four areas of investigation: 1) physical mesoscale studies, 2) frontal studies, 3) biological mesoscale studies of anchoveta and the upwelling ecosystem, and 4) biological mesoscale studies of the circulation and phytoplankton processes.

At the beginning of the CUEA program in 1972, the Peruvian upwelling region was selected as the site for JOINT–II. This selection was appropriate for the following reasons:

1. Concepts have been developed concerning processes that enhance the biological productivity off Peru as opposed to the other major upwelling regions of the world. These can now be tested.

2. The Peruvian research institutions—Instituto del Mar del Peru (IMARPE), National Meteorological and Hydrological Service (SENAMHI), Naval Hydrographic and Navigational Directorate (DHNM), Peruvian Geophysical Institution (IGP) —have initiated the program "A Study of the Coastal Upwelling System Off Peru." The Peruvian program includes the entire upwelling region along the Peru coast and detailed studies in four important anchoveta fishery regions. These studies complemented the intensive mesoscale studies of CUEA in JOINT–II.

3. Instituto del Mar del Peru (IMARPE) participated in the scientific program of JOINT–II through collaboration of IMARPE scientists with various CUEA components; by contributing one complete scientific component (Component 19, Zooplankton Fields); and by contributing the use of IMARPE space, facilities, and services for the JOINT–II investigation. This collaboration made it possible to compare the complex IMARPE fish stock models with CUEA ecosystem models. IMARPE and the Food and Agriculture Organization of the United Nations (FAO) have developed an assessment and prediction system using five independent determinations of abundance and catch. This program provides monthly predictions of anchoveta stocks. The opportunity exists to apply both IMARPE and CUEA capabilities into a tool for understanding and managing the protein resources of upwelling regions. In June 1975, a formal agreement was reached between CUEA and IMARPE on the areas of participation and collaboration.

Table 14.—U.S. institutions, investigators, and projects in CUEA program

Institutions	Investigators	Projects
University of Alaska	J. J. Goering	Consumption and Regeneration of Silicic Acid in Upwelling Systems
Bigelow Ocean Science Center	R. C. Dugdale	Kinetics of Nutrient Uptake Program Management
	J. MacIsaac	Kinetics of Nutrient Uptake
	T. T. Packard	Enzymatic Determination of Biological Transformation
Brookhaven National Laboratories	J. J. Walsh	Systems Model of Upwelling Ecosystems
	T. E. Whitledge	Nutrient Regeneration and Excretion
University of Delaware	C. N. K. Moores	Physical Dynamics of the Frontal Zone
Duke University	R. T. Barber	Primary Production, Chelation, and Toxicity Program Management
	S. Huntsman	Primary Production, Chelation, and Toxicity
Florida State University	Y. Hsueh	Diagnostic Modeling Studies in JOINT–II
	J. J. O'Brien	Simulation of Time-Dependent Coastal Upwelling Circulation
	D. W. Stuart	Meteorological Support for the JOINT-II Expedition
Inter-American Tropical Tuna Commission	M. R. Stevenson	Study of Frontal Dynamics and Mesoscale Circulation In Coastal Upwelling Zones by Lagrangian Measurements
University of Miami	J. C. Van Leer	Physical Dynamics of the Frontal Zone
Oregon State University	J. S. Allen	Theoretical Studies and the Dynamical Interpretation of Flow Field Observations
	A. Huyer	Mesoscale Hydrography During JOINT–II
	R. L. Smith	Mesoscale Circulation in Coastal Upwelling Systems; Program Management
San Francisco State College	J. C. Kelley	Nutrient and Phytoplankton Fields; Interactive Real-Time Information System (IRIS)
Scripps Institution of Oceanography	K. L. Smith, Jr.	Carbon, Nitrogen, and Phosphorus Cycles on the Sea Floor of an Upwelling Region
University of Washington	D. Halpern	Near-Surface Circulation Studies in a Coastal Upwelling Environment
	L. A. Codispoti	Mesoscale Hydrography During JOINT–II
	O. A. Mathisen and R. E. Thorne	Acoustic Assessment of Nekton
Woods Hole Oceanographic Institution	E. Rowe	Carbon, Nitrogen, and Phcsphorus Cycles on the Sea Floor of an Upwelling Region

4. The Latin American Countries along the Pacific Coast have initiated the study "Estudio Regional del Fenomeno El Niño" (ERFEN). This program monitors the oceanic and atmospheric environment from about 10° N to 35° S, extending west 500 km from South America. It documents the large-scale climatic and oceanographic features within the JOINT–II study area. JOINT–II results will increase our understanding of the El Niño phenomenon by identifying mesoscale processes that are driven by the large-scale disturbance and which cause the productivity of the region to collapse.

CUEA Data

CUEA data are available from NODC as follows:

NODC Accession No.: 76–1418
Organization: Oregon State University
Investigators: R. D. Pillsbury, J. S. Bottero, R. E. Still, and E. Mittelstaedt
Grant No.: NSF/GX–33502
Project: CUEA/JOINT–I
Data: Data from 9 Aanderaa current meters moored off the African coast between February 23 and April 25, 1974. Data consist of current velocity and north and east components; water temperature, pressure, and salinity; and surface winds and temperatures. Data on NODC–compatible magnetic tape.

NODC Accession No.: 76–1900
Organization: Oregon State University
Investigator: Jane Huyer
Grant No.: NSF/GX–33502
Project: CUEA/JOINT–I
Data: 48 Hydrocasts and 193 high-resolution CTDs taken aboard RV Gilliss Cruise GS–7401 off the west coast of Africa. Data on NODC–compatible magnetic tape.

NODC Accession No.: 77–0107
Organization: University of Ghana
Investigator: R. Houghton, Dalhousie University
Grant No.: NSF/IDO71–04211 (R. L. Smith)
Project: Ghana Upwelling 1974
Data: 3 Aanderaa current meters at 3 depths on a common mooring in the Gulf of Guinea, May 28, 1974 to August 15, 1974.

NODC Accession No.: 77–0054
Organization: Bigelow Laboratory for Ocean Science
Investigator: R. C. Dugdale
Grant No.: NSF/IDO72–06422
Project: Productivity studies—JOINT–1
Data: 43 productivity stations taken aboard RV Atlantis–II, Cruise 82, February 2, 1975 off the west coast of Africa.

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Barber, R. T., S. A. Huntsman, and J. E. Kogelschatz. 1976. OUTFALL I, April, 1972; MESCAL II, April, 1973; OUTFALL II, May, 1973; F. S. Meteor Reise 36, February 1975 EL NIÑO WATCH Cruise, February-May, 1975. CUEA Data Rep. No. 32, 173 p.

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Seagrass Ecoysystem Study (SES)

This study was begun in July 1974 to provide information about the benthic marine ecosystem, particularly the dynamic processes by which seagrass ecosystems are maintained, the distribution of these ecosystems, and their contribution to the seas. Initiation of these research activities has resulted from increased awareness of the importance of nearshore waters in the productivity of the ocean and the vulnerability of these waters to man-induced changes. The increased emphases on nearshore renewable resources led to recognition of how little is known about this important ecosystem.

The Seagrass Ecosystem Study generally addresses three main questions. What are the contributions of seagrass ecosystems to food webs, nutrient and mineral cycling, and coastal stabilization? What processes in seagrass ecosystems are affected by environmental changes or man-induced perturbations? Are there structural patterns in these ecosystems that allow them to persist in changing environments?

The SES program has initiated special field studies and laboratory experiments to answer these questions. Later phases of study will emphasize coordinated, intensive field studies and establishment of a network of national and international field sites for follow-on experiments.

Participants in the SES programs are identified in table 15. International collaboration is maintained through the International Seagrass Committee. Its members include Tom Fenchel, Denmark; C. den Hartog, The Netherlands; Akihiko Hattori, Japan; C. Peter McRoy and Patrick L. Parker, United States; and J. M. Peres, France.

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Diadema antillarium, *long-spined sea urchin, feeding on Caribbean reef seagrass*

Table 15.—U.S. institutions, investigators, and projects in SES program

Institutions	Investigators	Projects
University of Alaska	C. P. McRoy	Process Succession of Seagrass Ecosystems
Fairleigh Dickinson University	J. C. Ogden	Caribbean Seagrass Food Web Study
Florida State University	R. L. Iverson	Primary Productivity Studies in Seagrass Ecosystems
University of Hawaii	K. W. Bridges	Systematic Ecology
Michigan State University	M. J. Klug and R. G. Wetzel	Decomposition of Dissolved and Particulate Organic Detritus in Seagrass Ecosystems
Seattle Pacific College	R. C. Phillips	The Interrelationships of Phenology and Transplanting in the Analysis of Seagrass Stability
University of Texas	P. L. Parker	Stable Carbon Isotope Ratios of Food Webs and Biogeochemical Cycles in Seagrass Ecosystems
	C. McMillan	Environmental Tolerances of Seagrasses
University of Virginia	J. C. Zieman	Caribbean Seagrass Food Web Study

Appendix A—ROSCOP Summaries

In the following ROSCOP (Report of Observations/Samples Collected by Oceanographic Programs) summaries,* all institutions or activities are U.S. participants in IDOE and all projects are part of the Declared National Program (DNP) for Marine Data Exchange. All IDOE-related ROSCOP's received by NOAA's Environmental Data Service from April 1976 to April 1977 are included in this appendix. The reported ROSCOPs bring the IDOE 1970–77 total to 467. Information is presented in the following order:

Line 1: Name of vessel or platform used to collect the data, name of institution operating the vessel or platform**, ship cruise number.

Line 2: Inclusive dates of the cruise or platform deployment; general ocean area of cruise; and 10° Marsden square(s) where observations and samples were collected, as shown by charts following Appendices.

Line 3: NODC Reference Number. (Reference to this number when requesting ROSCOPs facilitates retrieval of the information.)

Line 4: Name of Principal Investigator or chief scientist on the cruise, his affiliate institution***, and the identifying number of the NSF grant that supports the principal investigator.

Line 5: Name of the program and project of the International Decade of Ocean Exploration for which the cruise data and collections were made.

A listing of parameters by discipline and the number of stations, observations, samples, or miles of record follow line 5. Where continuous sampling or observing has been made, the number of miles is used rather than discrete values.

LIST OF ABBREVIATIONS

Institution of IDOE Grant Holder

BBS	Bermuda Biological Station
CUNY	City University of New York
DUML	Duke University Marine Laboratory
IGPP	Institute of Geophysics and Planetary Physics
LDGO	Lamont-Doherty Geological Observatory
MIT	Massachusetts Institute of Technology
MLML	Moss Landing Marine Laboratory
NMFS	National Marine Fisheries Service, NOAA
OSU	Oregon State University
PEG/NMFS	Pacific Environmental Group, NMFS, NOAA
PMEL	Pacific Marine Environmental Laboratory, ERL, NOAA
RSMAS	Rosensteil School of Marine and Atmospheric Sciences, University of Miami
SEA	Sailing Education Association
SIO	Scripps Institution of Oceanography
SKIO	Skidaway Institute of Oceanography
TAMU	Texas A&M University
UC	University of California
UGA	University of Georgia
UHI	University of Hawaii
URI	University of Rhode Island
U Wash.	University of Washington
WHOI	Woods Hole Oceanographic Institution

Organizations providing support:

AEC	Atomic Energy Commission
EPA	Environmental Protection Agency
NSF–IDOE	National Science Foundation—International Decade of Ocean Exploration program
ONR	Office of Naval Research

* See Introduction.
** Certain cooperative data collection efforts were performed on vessels other than those of the grant holder's parent institution.
*** Certain inventory forms were submitted by institutions other than those of the grant holders.

Geochemical Ocean Sections (GEOSECS) Study

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 1
2. August 22 to September 10, 1973, Eastern North Pacific, MS—088, 121, 122, 123, 124
3. NODC Reference No. R391210
4. H. Craig (SIO), Grant No. NSF/OCE 76–05058
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 2,666 nmi, magnetism
Physical/Chemical Oceanography: Sea swell 10, continuous surface temperature and salinity, classical oceanographic stations 10, STD CTDs 9, XBTs 34, oxygen, phosphates, nitrates, nitrites, silicates, alkalinity, trace elements, isotopes, dissolved gasses, suspended solids, petroleum residues 4 each, radioactivity 5, total organic carbon 1

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 2
2. September 15 to October 6, 1973, Central North Pacific, MS—088, 089, 125, 126, 162, 198
3. NODC Reference No. R391211
4. W. S. Broecker (LDGO), Grant No. NSF/OCE 76–04245
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 2,588 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 8; continuous surface temperature and salinity, classical oceanographic stations 8, STD CTDs 7, XBTs, oxygen, phosphates, nitrates, nitrites, silicates, suspended solids 7 each, alkalinity, trace elements, isotopes, dissolved gases, petroleum residues 6 each, radioactivity 8, total organic carbon 5

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 3
2. October 7 - 26, 1973, Western North Pacific, MS—129, 130, 153, 154, 198
3. NODC Reference No. R391212
4. T. Takahashi (CUNY), Grant No. NSF/OCE72–06419
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry—2, 517 nmi; magnetism
Physical/Chemical Oceanography: Sea/swell 6, continuous surface temperature and salinity, classical oceanographic stations 6, STD/CTDs 6, XBTs, oxygen, phosphates, nitrates, nitrites, silicates, radioactivity, isotopes 6 each, alkalinity, dissolved gases, suspended solids, petroleum residues, total organic carbon 5 each, trace elements 3, partial carbon dioxide 2

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 4
2. October 31 to November 29, 1973, central Pacific, MS—053, 054, 055, 056, 091, 127, 128
3. NODC Reference No. R391213
4. D. W. Spencer (WHOI), Grant No. NSF/OCE76–04323
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 4,608 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 10, continuous temperature and salinity, classical oceanographic station 10, STD/CTDs 10, XBTs, oxygen, phosphates, nitrates, nitrites, silicates 10, alkalinity, radioactivity, isotopes, dissolved gases, petroleum residues 7 each, pH 3, trace elements 5, suspended solids 9, total organic carbon 5

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 5
2. December 4 - 29, 1973, central Pacific, MS—017, 018, 019, 053, 318, 354
3. NODC Reference No. R391214
4. R. F. Weiss (SIO)
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 3,392 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 20, continuous temperature and salinity, classical oceanographic stations 20, STD/CTDs 20, XBTs, oxygen, phosphates, nitrates, nitrites, silicates 20 each, alkalinity, isotopes, dissolved gases 11 each, pH 2, trace elements 5, radioactivity 13, suspended solids 19, petroleum residues 10

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 6
2. January 2 - 29, 1974, Southwest Pacific, MS—316, 352, 353, 389, 425
3. NODC Reference No. R391215
4. P. E. Biscaye (LDGO), Grant No. NSF/OCE76–04245
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 3,199 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 24, continuous surface temperature and salinity, classical oceanographic stations 24, STD/CTDs 24, XBTs, oxygen, phosphates, nitrates, silicates 20 each, nitrites 15, alkalinity, pH, isotopes, dissolved gases 9 each, trace elements 5, radioactivity 13, suspended solids 23, petroleum residues 8, total organic carbon 2

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 7
2. February 5 to March 9, 1974, South Pacific, MS—497, 498, 499, 533, 534
3. NODC Reference No. R391216
4. J. M. Edmond (MIT), Grant No. NSF OCE72–06432 A03
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 3,822 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 16, continuous surface temperature and salinity, classical oceanographic stations 16, STD CTDs 7, XBTs, oxygen phosphates, nitrates, silicates, trace elements 14 each, alkalinity 8, radioactivity 11, isotopes, suspended solids, petroleum residues 9 each, dissolved gases 5, total organic carbon 6

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 8
2. March 13 to April 8, 1974, Southwest Pacific, MS—387, 388, 424, 425, 460, 461
3. NODC Reference No. R391217
4. H. Craig (SIO), Grant No. NSF GX–28163 A1
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophypics: Bathymetry 3,410 nmi, magnetism
Physical/Chemical Oceanography: Seal swell 20, continu-

ous surface temperature and salinity, classical oceanographic stations 20, STD/CTDs 19, XBTs, oxygen, phosphates, nitrates, silicates 19 each, nitrites 11, alkalinity, radioactivity, isotopes, dissolved gases, petroleum residue 8 each, trace elements 4, suspended solids 6

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 9
2. April 12 to May 9, 1974, South Pacific, MS—348, 384, 386, 420, 421, 456
3. NODC Reference No. R391218
4. P. Brewer (WHOI), Grant No. NSF OCE72–06421 A03
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophysics: Bathymetry 4,651 nmi, magnetism
Physical/Chemical Oceanography: Sea/swell 10, continuous surface temperature and salinity, classical oceanographic stations 10, STD CTDs 10, XBTs, oxygen 10, phosphates, nitrates, nitrites, silicates, radioactivity 8 each, alkalinity, isotopes, dissolved gases 7 each, trace elements 4

1. RV MELVILLE (SIO) Cruise GEOPAC Leg 10
2. May 13 to June 10, 1974, eastern Pacific, MS—013, 049, 085, 312, 348, 349
3. NODC Reference No. R391219
4. W. S. Broecker (LDGO) Grant No. NSF/OCE76–04245
5. **Program:** IDOE/EQ–GEOSECS

Geology/Geophyscs: Magnetism
Physical/Chemical Oceanography: Sea swell 23, continuous surface temperature and salinity, classical oceanographic stations 23, STD CTDs 23, oxygen, phosphates, nitrates, silicates 23 each, nitrites 20, alkalinity 10, trace elements 8, radioactivity, suspended solids 22 each, isotopes, dissolved gases 9 each, petroleum residues 19

Pollutant Transfer Program

1. RV CAYUSE (OSU) CALOC–76 Leg I
2. February 3 - 22, 1976, eastern Pacific, MS—120, 121, 122
3. NODC Reference No. R391086
4. W. Broenkow (MLML), J. H. Martin (MLML), Grant No. NSF/IDO75–01303
5. **Program:** IDOE EQ–Pollutant Transfer/Baja III

Biology: Phytoplankton 6
Physical/Chemical Oceanography: Continuous temperature and chlorophyll 1,065 nmi, classical oceanographic stations 2, CTDs 19, heavy metals, chlorinated hydrocarbons 6 each

1. RV CAYUSE (OSU) Cruise CALOC–76 Leg II
2. February 23 to March 3, 1976, eastern Pacific, MS—120
3. NODC Reference No. R391085
4. J. Martin (MLML), Grant No. NSF/IDO75–01303
5. **Program:** IDOE/EQ–Pollutant Transfer/Baja–III

Physical/Chemical Oceanography: Classical oceanographic stations 2, CTDs 10, transparency 16, phosphates 47, special salinities 16, heavy metals 47, chlorinated hydrocarbons 6

1. RV CAYUSE (OSU) Cruise CALOC–76 Leg III
2. March 4 - 13, 1976, eastern Pacific, MS–083, 084, 120
3. NODC Reference No. R391083
4. R. Risebrough (UC, Berkeley), Grant No. NSF/IDO75–01303
5. **Program:** IDOE/EQ–Pollutant Transfer/Baja III

Geology/Geophysics: Cores 2
Physical Chemical Oceanography: Continuous temperature and chlorophyll 1,400 nmi; CTDs 3, transparency 6, chlorinated hydrocarbons 6

1. RV CAYUSE (OSU) Cruise CALOC–76 Leg IV
2. March 14 to April 2, 1976, eastern Pacific, MS–083, 084, 120
3. NODC Reference No. R391084
4. K. Bruland (UC Santa Cruz), Grant No. NSF IDO75X 01303
5. **Program:** IDOE EQ–Pollutant Transfer Baja III

Biology: Zooplankton 10, phytoplankton 9
Physical/Chemical Oceanography: Continuous temperature and chlorophyll 1,500 nmi, classical oceanographic stations 2, CTDs 4, heavy metals 9, chlorinated hydrocarbons 9

1. RV GYRE (TAMU) Cruise 75–G–13
2. October 1 - 12, 1975, Gulf of Mexico, MS—082
3. NODC Reference No. R391272
4. J. M. Brooks (TAMU), Grant No. NSF IDO73–09739 #2
5. **Program:** IDOE/EQ–Pollutant Transfer

Geology/Geophysics: Cores 8, chemical analyses of sediment 8
Biology: Primary productivity 2, phytoplankton pigments 5, particulate organic carbon 4, dissolved organic matter 4, phytoplankton 10, hydrocarbon concentrations 29
Physical/Chemical Oceanography: Discrete temperature and salinity, at surface 26, at bottom 15, classical oceanographic stations 25, oxygen, phosphates, phosphorous, nitrates, silicates, chlorinity, dissolved gases 25 each, ph 5, isotopes 5

1. RV GYRE (TAMU) Cruise 76–G–10
2. October 9 - 30, 1976, Gulf of Mexico, MS—081, 082
3. NODC Reference No. R391479
4. B. J. Presley (TAMU), R. Shokes (TAMU), Grant No. NSF/GX–42576
5. **Program:** IDOE/EQ–Pollutant Transfer

Geology/Geophysics: Bathymetry 2,000 nmi, seismic reflections 100 nmi, chemical analysis of sediments 50
Physical/Chemical Oceanography: Swallow floats 2, discrete temperatures 80, discrete salinities 100, STD/CTDs 2, XBTs 80, oxygen, phosphates, nitrates, silicates, chlorinity 100 each, pH 25, trace elements 80, isotopes 4, heavy metals 30

1. RV KIT JONES (UGA) Cruise K75–40
2. October 6, 1975, Off Sapelo Is., Georgia, MS—117
3. NODC Reference No. N/A
4. J. D. Howard (UGA), Grant No. NSF/GX–39999X
5. **Program:** IDOE/EQ–Pollutant Transfer

Pollutants: Biogenic energy transfer

1. RV KIT JONES (UGA) Cruise K75–42
2. October 10, 1975, Off Sapelo Is., Georgia, MS–117
3. NODC Reference No. N A
4. J. D. Howard (UGA), Grant No. NSF/GX–39999X
5. **Program:** IDOE/EQ–Pollutant Transfer

Pollutants: Biogenic energy transfer

1. RV KIT JONES (UGA), Cruise K75–43
2. October 13 - 16, 1975 Off Sapelo Is., Georgia, MS–117
3. NODC Reference No. N/A
4. W. Dunstan/W. Gardner (UGA), Grant No. NSF/DES 74–14917, H. Windom (UGA), Grant No. NSF/IDO72–06423, R. F. Lee, Grant No. NSF/GX–42582
5. **Program:** IDOE/EQ–Pollutant Transfer

Pollutants: Heavy metals in organisms, petroleum hydrocarbons in food chains

1. RV KIT JONES (UGA) Cruise K75–47
2. October 27 - 30, 1975, Off Sapelo Is., Georgia, MS–117
3. NODC Reference No. N/A
4. H. L. Windom (UGA), Grant No. NSF/IDO72–06423
5. **Program:** IDOE/EQ–Pollutant Transfer

Pollutants: Heavy metals in organisms

Mid-Ocean Dynamics Experiment (MODE) and POLYMODE

1. RV CHAIN (WHOI) Cruise 122
2. May 23 to June 7, 1975, North Atlantic, MS–110, 111, 112, 113, 114, 115
3. NODC Reference No. R390529
4. G. Seaver (MIT), Grant No. NSF/IDO75-04215
5. **Program:** IDOE/EF–POLYMODE

Physical/Chemical Oceanography: Continuous salinity 15 days, classical oceanographic station 13, XBTs 312, phosphates, nitrates, nitrites, ammonia, urea, nitrogen fixation 78 each
Biology: Invertebrate nekton 26, pelagic eggs and larvae 26, ATP–ADP–AMP concentrations 13, primary production, phytoplankton pigments, pelagic bacteria, and microorganisms 13 each

1. RV CHAIN (WHOI) Cruise 127 Leg 2
2. October 4 - 26, 1975, North Atlantic, MS–078, 079, 114, 115
3. NODC Reference No. R390803
4. E. Katz (WHOI), Grant No. NSF IDO72–064311AO
5. **Program:** IDOE/EF–MODE

Geology/Geophysics: Bathymetry 2,100 nmi
Physical/Chemical Oceanography: Continuous temperature 2,100 nmi, STD CTDs 3, XBTs 95, horizontally towed STD 13.7 hours

1. RV CHAIN (WHOI) Cruise 129
2. December 3 - 23, 1975, western North Atlantic
3. NODC Reference No. R391069
4. K. F. Bradley (WHOI), Grant No. NSF OCE75–03962
5. **Program:** IDOE/EF–POLYMODE

Geology/Geophysics: Bathymetry 1,500 nmi
Physical/Chemical Oceanography: Current meters 26

1. RV JAMES M. GILLISS (RSMAS) Cruise GS–7602
2. February 28 to March 13, 1976, western North Atlantic, MS–080.
3. NODC Reference No. R391177
4. H. T. Rossby (URI), Grant No. NSF/IDO75–18930
5. **Program:** IDOE/EF–POLYMODE

Geology/Geophysics: Bathymetry 1,000 nmi
Physical Oceanography: Current meters 1 array, SOFAR floats 5, XBTs 176

1. RV KNORR (WHOI) Cruise 54 Leg 4
2. March 2 to April 1, 1976, western North Atlantic, MS–043, 079, 078, 077, 076, 075, 074, 109, 110
3. NODC Reference No. R391244
4. B. Owens (WHOI), Grant No. NSF/IDO75–03962
5. **Program:** IDOE/EF–POLYMODE

Geology/Geophysics: Bathymetry, magnetism 6,500 nmi, seismic reflection 3,160 nmi
Physical Oceanography: XBTs 200

1. RV KNORR (WHOI) Cruise 60
2. September 29 to October 28, 1976, western North Atlantic, MS–114, 115, 150, 151
3. NODC Reference No. R391658
4. K. F. Bradley (WHOI), Grant No. NSF OCE75–03962
5. **Program:** IDOE/EF–POLYMODE

Meterology: Standard observations 323
Physical/Chemical Oceanography: Discrete temperatures 323, classical oceanograhic stations 29, STD/CTDs 17, XBTs 323, oxygen 754, silicates 799, current meter stations 36, drifters 1, sea swell 29
Geology/Geophysics: Bathymetry 3,000 nmi

1. RV OCEANUS (WHOI) Cruise 15
2. September 18 to October 8, 1976, western North Atlantic, MS–079, 080, 116, 152
3. NODC Reference No. R391495
4. H. T. Rossby (URI), Grant Nos. NSF/OCE75–18930 AO1, NSF/OCE76–11726; D. Webb (WHOI), Grant No. NSF/OCE75–18931 AO2
5. **Program:** IDOE/EF–POLYMODE

Geology/Geophysics: Bathymetry 780 nmi.
Physical Oceanography: Current meters 4, SOFAR floats 6, STD/CTDs 34, XBTs 320

1. RV TRIDENT (URI) Cruise TR–133
2. March 12 to April 4, 1973, western North Atlantic, MS–079, 080, 115, 116
3. NODC Reference No. R390783
4. R. Scarlett (EG&G, Inc.), Grant No. NSF GX–31340
5. **Program:** IDOE/EF–MODE–I

Physical Oceanography: Current meters 7 stations recovered, 13 meters, 107.7 days average duration of measurements, classical oceanographic stations 2, STDs 44

North Pacific Experiment (NORPAX)

1. RV KANA KEOKI (UHI) Cruise No. ADS–1
2. June 18 to July 18, 1976, Western North Pacific, MS–127, 128, 163, 164
3. NODC Reference No. R391471
4. W. B. White (SIO), Grant No. NSF OCE75–23364, R. L. Bernstein (SIO), Grant No. NSF/OCE75–23361, NSF/OCE76–10177
5. **Program:** IDOE/EF–NORPAX

Physical/Chemical Oceanography: Discrete temperature 349, discrete salinity 326, classical oceanographic stations 55, CTDs 55, XBTs 216

1. RV WECOMA (OSU) Cruise No. WELOC–76 Leg 2
2. August 29 to October 6, 1976, central North Pacific, MS–125, 126, 161, 162
3. NODC Reference No. R391573
4. R. L. Bernstein (SIO), A. D. Kirwan (TAMU), Grant No. NSF/IDO76–10177
5. **Program:** IDOE/EF–NORPAX

Meteorology: Standard observations 80
Physical/Chemical Oceanography: Discrete salinities 102,

classical oceanographic stations 79, CTDs 79, MBT 134, other measurements 60

NORPAX–XBT's–Pacific Ships of Opportunity

1. AUSTRALIAN MOON, Track from Papeete to Los Angeles
2. September 29 to October 4, 1976, North Pacific, MS–121, 085, 050, 014, 314, 350
4. D. McLain (PEG NMFS), Grant No. NSF OCE75–23357
5. **Program:** IDOE EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 1, XBTs 109

1. CALIFORNIAN, Tracks between San Francisco, Los Angeles, and Honolulu
2. July 31, 1974 to August 12, 1976, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 23, XBTs 775

1. CALIFORNIAN, Tracks between Portland, Seattle, and Honolulu
2. January 26, 1975 to December 30, 1976, eastern North Pacific, MS–157, 158, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 29, XBTs 1,111

1. CHEVRON CALIFORNIA, Tracks between Los Angeles, San Francisco, and Honolulu
2. June 4, 1975 to January 15, 1977, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 5, XBTs 310

1. CHEVRON HAWAII, Tracks between Honolulu and Alaska
2. August 19, 1974 to February 1, 1975, North Pacific, MS–088–124, 160, 196, 195, 159
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 4, XBTs 148

1. CHEVRON HAWAII, Tracks between Los Angeles, San Francisco, and Honolulu
2. October 15, 1975 to December 22, 1976, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 7, XBTs 229

1. HAWAIIAN, Tracks between San Francisco, Seattle, and Honolulu
2. June 22, 1975 to March 21, 1976, eastern North Pacific, MS–157, 158, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 3, XBTs 97

1. HAWAIIAN ENTERPRISE, Tracks between San Francisco, Los Angeles, and Honolulu
2. July 12, 1974 to October 10, 1976, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 52, XBTs 1,368

1. HAWAIIAN QUEEN, Tracks between San Francisco, Los Angeles, and Honolulu
2. July 14, 1974 to January 25, 1977, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 61, XBTs 1,914

1. HAWAIIAN QUEEN, Tracks between Seattle and Honolulu
2. December 12–25, 1975, eastern North Pacific, MS–157, 158, 122, 123, 087, 088
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 2, XBTs 57

1. MARIPOSA, Tracks between San Francisco, Los Angeles, and Honolulu
2. July 3, 1974 to February 21, 1975 eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 11, XBTs 265

1. MONTEREY, Tracks between Pago Pago, Papeete, Bora Bora, Rootonga, Nukualofa, and Honolulu
2. October 7, 1974 to March 9, 1975, central Pacific
4. D. McLain (PEG/NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of cruises 13, XBTs 244

1. MONTEREY, Tracks between San Francisco, Los Angeles, and Honolulu
2. November 16, 1974 to March 26, 1975, eastern North Pacific, MS–121, 122, 123, 087, 088
4. D. McLain (PEG NMFS), Grant No. NSF/OCE75–23357
5. **Program:** IDOE/EF–NORPAX/Pacific Ships of Opportunity. Number of crossings 10, XBTs 234

International Southern Ocean Studies (ISOS)

1. RV THOMPSON (U. Wash.) Cruise F DRAKE 76 Leg I
2. February 4 - 23, 1976, Drake Passage, MS–485, 521
3. NODC Reference No., R391067
4. W. D. Nowlin, Jr., (TAMU), Grant No. NSF/OCE76–80410
5. **Program:** IDOE EF–ISOS F DRAKE 76

Meteorology: Standard weather observations 25
Physical/Chemical Oceanography: Continuous temperature and salinity recording 1,500 nmi, discrete temperatures 56, discrete salinities 58, classical oceanographic stations 21, oxygen, phosphates, nitrates, silicates 21 each, STD/CTDs 25, XBTs 64, current meters 8, drift cards released 275, tidal observations 1 year
Geology/Geophysics: Bathymetry 1,500 nmi

1. RV THOMPSON (U. Wash.) Cruise F DRAKE 76 Leg II
2. February 25 to March 11, 1976, Drake Passage, MS–485, 521
3. NODC Reference No., R391068
4. W. D. Nowlin, Jr., (TAMU), Grant No. NSF/OCE76–80410
5. **Program:** IDOE EF–ISOS F DRAKE 76

Meteorology: Standard weather observations 33
Physical/Chemical Oceanography: Continuous temperature and salinity 1,800 nmi, discrete temperatures 68, discrete salinities 67, classical oceanographic stations 22, oxygen, phosphates, nitrates, nitrites, silicates 22 each, STD/CTDs 33, XBTs 68, drift cards 950
Geology/Geophysics: Bathymetry 1,800 nmi

1. RV THOMPSON (U. Wash.) Cruise No. TT107 Leg III
2. March 13 to April 9, 1976, Drake Passage, MS–486
3. NODC Reference No. R391106
4. T. Joyce (WHOI) Grant No. OCE75–14056 AO1
5. **Program:** IDOE EF–ISOS F DRAKE 76

Geology/Geophysics: Bathymetry 800 nmi
Physical/Chemical Oceanography: Current meters 19, swallow floats 4, STD/CTDs 101, XBTs 450, transparency 11, optics 47, oxygen, phosphates, nitrates, silicates 101 each

1. A.G.S. YELCHO (Chile) Cruise F DRAKE 76
2. February 27 to April 8, 1976, Drake Passage, MS–485, 486, 522
3. NODC Reference No., R070001
4. H. A. Seivers (Chile) and S. L. Patterson (TAMU), Grant No., OCE76–80410
5. **Program:** IDOE EF–ISOS F DRAKE 76

Meteorology: Standard weather observations 117
Physical/Chemical Oceanography: Discrete temperatures and salinities 569, XBTs 571

Plate Tectonics and Metallogenesis Studies

1. RV THOMAS WASHINGTON (SIO) Cruise INDOPAC Legs 2 and 3
2. May 5 to June 19, 1976, western tropical North Pacific, MS–059, 060, 061, 095, 096, 097, 131, 132
3. NODC Reference No. RE391227
4. J. L. Reid (SIO), Grant No. OCE 71–04197
5. **Program:** IDOE/SA–Plate Tectonics/Metallogenesis

Geological/Geophysical: Bathymetry 6,400 nmi
Biology: Zooplankton 12, neuston 10, nekton 1
Meteorological: Standard weather observations 56

Physical/Chemical Oceanography: Discrete temperatures and salinities 3, classical oceanographic stations 53, CTDs 56, XBTs 340, oxygen, phosphates, phosphorous, nitrates, nitrites, silicates 53 each

Galapagos Spreading Center

1. RV MELVILLE (SIO) Cruise PLEIADES Leg II
2. June 13 to July 11, 1976, eastern equatorial Pacific, MS–009
3. NODC Reference No. R391198
4. J. B. Corliss (OSU), J. P. von Herzen (WHOI), Grant No. NSF/IDE76–00389
5. **Program:** IDOE SA–Galapagos Rift Hydrothermal Study

Geological/Geophysical: Dredges 4, grabs 3, cores 46, bottom photos 10, sea floor temperature profiles 9, heat flow profiles 22, bathymetry 1,320 nmi, seismic refraction 68, paleontology 46
Physical/Chemical Oceanography: Discrete temperatures, salinities, surface 21, near sea floor 9, oxygen, phosphates, phosphorous, nitrates, nitrites, silicates, alkalinity, pH, trace elements, isotopes, dissolved gases 21 each

Nazca Plate

1. RV WECOMA (OSU) Cruise W7610–B Leg I
2. October 28 - 30, 1976, eastern North Pacific, MS–157
3. NODC Reference No. R391578
4. L. D. Kulm (OSU), Grant No. NSF IDO71–04208 AO8
5. **Program:** IDOE SA–Nazca Plate

Geology/Geophysics: Cores 16

SEATAR

1. RV ATLANTIS–II (WHOI) Cruise 93 Legs 12 & 13
2. September 2 to October 25, 1976, Banda Sea, MS–059, 060
3. NODC Reference No. R391656
4. C. Bowin (WHOI), Grant No. NSF OCE75–19150
5. **Program:** IDOE SA–Metallogenesis–SEATAR

Geology/Geophysics: Dredge 1, grabs 3, cores 9, bathymetry 8,223 nmi, seismic refraction 1,287 nmi, seismic reflection 3,751 nmi, gravity 8,234 nmi, magnetism 6,212 nmi, geothermy 12

Manganese Nodule Study

1. RV MELVILLE (SIO) Cruise PLEIADES Leg I
2. April 24 to June 7, 1976, equatorial eastern Pacific, MS–011, 310, 009, 010
3. NODC Reference No. R391287
4. P. F. Lonsdale (SIO), R. Weiss (SIO), Grant No. NSF/OCE76–04724
5. **Program:** IDOE/SA–Manganese Nodules

Geology/Geophysics: Dredges 2, cores 16, bottom photos, seismic reflection 5,000 nmi, magnetism 3,000 nmi, physical analysis of sediments, chemical analysis, paleontology 16 each

Physical/Chemical Oceanography: Current meters 13, discrete temperatures and salinities at surface and near sea floor 50, continuous temperature and salinity 10 days, classical oceanographic stations 2, CTDs 15, XBTs 40, optics 10, oxygen, phosphates, nitrates, silicates, dissolved gases 5 each, trace elements 4

Coastal Upwelling Ecosystems Analysis (CUEA)

1. RV EASTWARD (DUML) Cruise No. E–14–75
2. November 28–30, 1975, western North Atlantic, MS–116
3. NODC Reference No. R391136
4. S. A. Huntsman (DUML), Grant No. OCE75–23722
5. **Program:** IDOE/LR–CUEA N.C. Shelf Study

Biology: Primary productivity 13, phytoplankton pigments, excretion of C14

Physical/Chemical Oceanography: Discrete surface and near bottom temperatures and salinities 14, STDs 14 transparency 5, phosphates, nitrates, nitrites, silicates, ammonia 14 each

1. RV EASTWARD (DUML) Cruise No. E–5D–76 (JASON Leg 0)
2. July 17 - 24, 1976, eastern South Pacific, MS—343
3. NODC Reference No. R391472
4. A. Huyer (OSU), Grant No. NSF/OCE76–00594
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Physcal/Chemical Oceanography: CTDs 8

1. RV EASTWARD (DUML) Cruise E–5E–76 (JASON Leg 1)
2. July 26 to August 2, 1976, eastern South Pacific, MS–343
3. NODC Reference No. R391473
4. R. L. Smith (OSU), Grant No. NSF/OCE76–00594
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Physical/Chemical Oceanography: Current meters 3, classical oceanographic stations 9, CTDs 41

1. RV EASTWARD (DUML) Cruise E–5F–76 (JASON Leg 2)
2. August 7–16, 1976, eastern South Pacific, MS—343
3. NODC Reference No. 391474
4. A. Huyer (OSU), Grant No. NSF/OCE76–00594
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Physical/Chemical Oceanography: Classical oceanographic stations 16, CTDs 67, oxygen, phosphates, phosphorous, nitrates, nitrites, silicates 16 each

1. RV EASTWARD (DUML) Cruise E–5G–76
2. August 24, 1976 to September 2, 1976, eastern South Pacific, MS–343
3. NODC Reference No. R391475
4. J. Walsh (Brookhaven Nat'l Lab.), Grant No. NSF/OCE–00137
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Meteorology: Incident radiation 9

Biology: Primary production 6, phytoplankton pigments 21, particulate organic carbon 6, phytoplankton 21, zooplankton 21, population, identification, distribution, biomass, food chains 21 each

Physical/Chemical Oceanography: Discrete temperatures and salinities, classical oceanographic stations, phosphates, nitrates, nitrites, silicates 21 each, transparency 6

1. RV EASTWARD (DUML) Cruise E–5H–76
2. September 9–25, 1976, eastern South Pacific, MS—343
3. NODC Reference No. R391476
4. T. T. Packard (Bigelow Labs), Grant No. NSF/OCE75–23718
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Meteorology: Standard measurements

Biology: Primary productivity 15, phytoplankton and pigments 36, zooplankton 18, pelagic larvae and eggs 18, others 72, taxonomy 36

Physical/Chemical Oceanography: Classical oceanographic stations 36, oxygen, phosphates, nitrates, nitrites, silicates, ammonia 36 each

1. RV EASTWARD (URI) Cruise E–5J–76 Leg 6
2. October 8 - 14, 1976, eastern South Pacific, MS—343
3. NODC Reference No. R391693
4. G. T. Rowe (WHOI), Grant No. NSF/OCE76–00134
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Geology/Geophysics: Grabs 10, cores 6, diver samples 2, bottom photos 7, sediment trap arrays 4, sediment oxygen and nutrient flux 2, sediment chemical analyses 6

Biology: Primary production 9, phytoplankton pigments 9, benthic bacteria 5, zoobenthos 10

Physical/Chemical Oceanography: Oxygen, phosphates, silicates, chlorinity 9 each

1. RV EASTWARD (URI) Cruise E–5K–76
2. October 18 - 26, 1976, eastern South Pacific, MS—343
3. NODC Reference No. R391694
4. G. T. Rowe (WHOI), Grant No. NSF/OCE76–00134
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Geology/Geophysics: Grabs 15, cores 15, diver samples 3, bottom photos 4, sediment oxygen and nutrient flux 3, sediment trap arrays 3

Biology: Primary production 19, phytoplankton pigments 19, zoobenthos 15

Physical/Chemical Oceanography: Oxygen, phosphates, total phosphorous, nitrates, nitrites, silicates, chlorinity 18 each

1. RV EASTWARD (URI) Cruise E–5L–76
2. October 29 to November 12, 1976, eastern South Pacific, MS—343
3. NODC Reference No. R391695
4. G. T. Rowe (WHOI), Grant No. NSF/76–00134, R. Jimenez (INOCAR, Ecuador)
5. **Program:** IDOE/LR–CUEA/JOINT–II 76

Geology/Geophysics: Grabs 24, cores 13, physical analyses of sediments 30, chemical analyses 30, organic matter 15

Biology: Primary productivity 90, phytoplankton pigments 90, zooplankton 6, zoobenthos 24, demersal fish 4, crustaceans 4, biomass determination 30, communities 30

Physical/Chemical Oceanography: Discrete temperatures and salinities 26, classical oceanographic stations 17, CTDs 19, oxygen, phosphates, nitrates, nitrites, silicates, chlorinity 17 each

1. RV T. G. THOMPSON (U. Wash.) Cruise No. TT–108 JOINT–II leg I
2. April 25 to May 13, 1976, eastern South Atlantic, MS–343
3. NODC Reference No. R391116
4. Louis Codispoti (U. Wash.) Grant No. OCE76–04825
5. **Program:** IDOE/LR–CUEA JOINT–II

Physical/Chemical Oceanography: CTDs 134, oxygen 23, phosphates, nitrates, nitrites, silicates, ammonia 75 each, chlorinity 109
Geology/Geophysics: Sea surface maps for temperature, salinity, nutrients
Biology: Primary productivity, phytoplankton pigments

1. RV T. G. THOMPSON (U. Wash) Cruise No. TT–108 JOINT–II leg II
2. May 17 to June 9, 1976, eastern South Atlantic, MS–343
3. NODC Reference No. 391174
4. J. C. Kelley (San Fran. State U.), Grant No. NSF/OCE 76–00135
5. **Program:** IDOE/LR–CUEA JOINT–II

Physical/Chemical Oceanography: Cyclosonde 1,500 nmi, continuous temperature and salinity 6, STD CTDs 57, oxygen, phosphates, nitrates, nitrites, silicates, ammonia
Biology: Primary productivity, phytoplankton pigments, phytoplankton, zooplankton, biomass

1. RV T. G. THOMPSON (U. Wash.) Cruise No. TT–108 JOINT–II leg III
2. June 3–24, 1976, eastern South Atlantic, MS–343
3. NODC Reference No. R391225
4. J. Goering (U. Alaska), Grant No. NSF OCE75–03678 A01
5. **Program:** IDOE LR–CUEA/JOINT–II

Geology/Geophysics: Cores 37
Biology: Primary productivity, phytoplankton pigments, phytoplankton, biomass determination 12 each, particulate organic carbon, particulate organic nitrogen 4 each, zoobenthos 15, trace metals and uptake of chemicals 14
Physical and Chemical Oceanography: Classical ocean stations, CTDs, phosphates, nitrates 12 each, silicates 14

1. RV WECOMA (OSU) Cruise No., W7605–A
2. May 8–9, 1976, western North Pacific, MS–157
3. NODC Reference No. R391158
4. A. J. Huyer (OSU) Grant No. NSF/I0071–04211
5. **Program:** IDOE/LR–CUEA

Physical/Chemical Oceanography: Continuous surface temperature and salinity, CTDs 28

1. RV WECOMA (OSU) Cruise W7610–A
2. October 23–25, 1976, eastern North Pacific, MS–157
3. NODC Reference No. R391574
4. L. Gordon, R. Smith, A. J. Huyer (OSU), Grant No. NSF/OCE76–00061
5. **Program:** IDOE/LR–CUEA

Physical/Chemical Oceanography: Classical oceanographic stations 3, CTDs 3, oxygen, phosphates, nitrates, silicates, dissolved gases 3 each

1. RV WECOMA (OSU) Cruise W7610–B Leg II
2. November 1 - 2, 1976, eastern North Pacific, MS–157
3. NODC Reference No. R391575
4. T. Chriss (OSU) Grant No. NSF/OCE76–00061
5. **Program:** IDOE/LR–CUEA

No data collected, gear testing only

1. RV WECOMA (OSU) Cruise W7611–A
2. November 3 - 8, 1976, eastern North Pacific, MS–157
3. NODC Reference No. R391576
4. H. Pak, H. Zaneveld (OSU), Grant No. NSF/OCE76–00061
5. **Program:** IDOE/LR–CUEA

Hydrography: Continuous temperature and salinity 72, discrete temperatures and salinities 12, CTDs 72, transparencies 72

1. RV WECOMA (OSU) Cruise W7611–B
2. November 10 - 11, 1976, eastern North Pacific, MS–157
3. NODC Reference No. R391577
4. J. Huyer (OSU), Grant No. NSF OCE76–00061
5. **Program:** IDOE/LR–CUEA

Physical Oceanography: CTDs 29

Appendix B—IDOE Films

The NSF Office for IDOE has prepared several films to illustrate phenomena of the ocean environment and the work of IDOE-funded scientists. These 16-mm, sound and color motion pictures are available from the organizations indicated. Abbreviations used are **F** for free loan, **R** for rental fee, and **P** for purchase.

Alpha Cine Labs
1001 Lenora Street
Seattle, WA 98121

Well of Life (27 minutes)—The twin dramas of the ocean's life cycles and the scientific probing of its mysteries are combined in this story of ocean upwelling. Coastal upwelling is the still little-understood process by which the ocean continuously renews its resources, through the motions of wind, water, and the Earth itself. The **Well of Life** deals with that mystery, and the efforts of scientists to uncover its driving forces and learn how it influences and is influenced by weather, climate, and the seemingly limitless round of ocean-linked phenomena. The setting is off the Oregon coast. But the truths presented about balance in the world's ecosystems and the relevance of one field of science to another have universal applications. (English, French, German, Spanish, and Russian versions.) **P**

Centre Films, Inc.
1103 N. El Centro Ave.
Hollywood, CA 90038

The Turbulent Ocean (60 minutes)—A documentary film about the planning and execution of one of the largest deep-sea expeditions in twentieth century oceanographic research. Over 75 scientists and technicians from 18 national and international universities and oceanographic institutions set forth in a coordinated, cooperative effort to find and measure strange and not yet understood motions beneath the surface of the sea called an eddy. **R** or **P**

Cineffects Color Laboratory
115 West 45th Street
New York, NY 10036

The Alchemist Sea (5 minutes)— For nearly 200 million years, the Earth's surface has broken up into massive plates, that shift and move—often beneath the sea floor. Scientists, collecting core samples from the sea floor, are discovering there's a relationship between plate motion and the distribution of ore deposits. Their research can help guide our search for metals on the sea floor as well as on continents. **P**

Changing Climes (5 minutes)—Are the unusual weather patterns and severe crop losses of recent years just a passing phenomenon? Or is the Earth sliding into a downward side of a long-term temperature cycle. Scientists are detecting evidence of such long-term cycles and are raising some early warnings. **P**

Where is the Weather Born? (5 minutes)—Weather and climate, it has been said, began in the oceans. A group of scientists have been studying the northern Pacific in the effort to identify the oceanic processes relating to weather conditions over the continents. NORPAX, the North Pacific Experiment, is an effort to understand the interrelationships, for instance, between sea-surface temperatures and long-term weather (or short-term climate). This research could lead not only to understanding, but to prediction. **P**

Living Resources Program
Office for the International
Decade of Ocean Exploration
National Science Foundation
Washington, DC 20550

Through the Eyes of IRIS (25 minutes)—A technical film report describing to potential users a computer-driven shipboard data acquisition system, IRIS (Interactive Realtime Information System), developed for the Living Resources Program, under the International Decade of Ocean Exploration.
The film shows how the system was tested during scientific voyages to West Africa, and Baja, California. A towed "Batfish", operating at up to 10 knots and at depths from 0 to 100 meters, reads temperature, salinity, and depth electronically, and draws samples at the same time. The IRIS system holds promise for many useful applications not only at sea, but also in earth and meteorological studies and management programs. **F**

Time Windows (12 minutes)—Using modern data transmission facilities, ocean scientists engaged in the International Decade of Ocean Exploration, are now able to exchange their data, reports, and findings as readily as dialing the telephone or tuning their television sets. Indeed, that's what happens: information stored in computers, linked by telephone give oceanographers across the land ready access to each others findings, which with the aid of an adapter are displayed on regular television sets or printed with the aid of a data facsimile machine. **F**

NOAA Film Library
12227 Wilkins Avenue
Rockville, MD 20852

Boundary of Creation (27 minutes)—This film describes the efforts of U.S. and French scientists in Project FAMOUS to understand the ever-changing geology of our Earth, particularly the midocean ridges off the Azores. The picture features the probes of the minisub ALVIN in the ocean depths and also portrays research in Hawaii and Iceland. **F**

RHR Filmedia, Inc.
1212 Avenue of the Americas
New York, NY 10036

Cycle in the Sea (5 minutes)—Thanks to the motions of wind, water, and the Earth itself, life in the oceans continuously renews itself. Here is an important story of the balance in the world's ecosystems and its study off the coast of Oregon. **F**

Desert in the Deep? (5 minutes)—That the ocean floor is no desert is beginning to be realized. But the varieties of life forms, from simple organisms to sharks measuring 4 feet between the eyes, were unsuspected until scientists went to sea with cameras able to explore the very deepest reaches of the ocean. **F**

Pastures of the Sea (5 minutes)—Food chains in the sea like food chains on land depend on plants to use the Sun's energy to convert chemical nutrients into food. To understand, and perhaps better use, the resources of the sea, we have to understand its interlocking life cycles. Science is looking at the beginning of the sea's food chain; this film looks at the science. **F**

Rivers of the Sea (27 minutes)—A sea-going expedition leaves Tahiti to gain a better understanding of the oceans and their chemistry—knowledge that is vital in preventing ocean polluton, improving commercial fishing, and understanding climatic conditions. It joins scientists working at sea and in land-based laboratores in California, New York, and Miami. **F**

Science and the Salmon Fishery (5 minutes)—Commercial fishermen have learned by guess and by gosh where to catch fish, but they don't often know why the fish are where they are. A scientific experiment off the Oregon coast is turning up explanations and, with the cooperation of the coho salmon fishermen, is developing a system of fisheries predictions that seems to be paying off. **F**

Test Tubes in the Sea (5 minutes)—Can our oceans continue to absorb the urban wastes, oils, and chemicals we discharge into them—or is there a point of no return? An international team of scientists and engineers is trying to find out by measuring pollutants in the sea. Their efforts are giving us a major tool that will help us understand how these contaminants affect the ocean food chain and an indication of how far we can go in continuing to pollute the sea. **F**

Appendix C—Recent Reports and Workshops Sponsored by IDOE

Federal Agency Support For Marine-Related Social Science Research. A Report Prepared by the ad hoc Subcommittee for the Interagency Committee on Marine Science and Engineering, December 1976.

Transient Tracers in the Ocean. A Report to the International Decade of Ocean Exploration, National Science Foundation, of a Design Workshop held at Lamont–Doherty Geological Observatory, February 10-12, 1977.

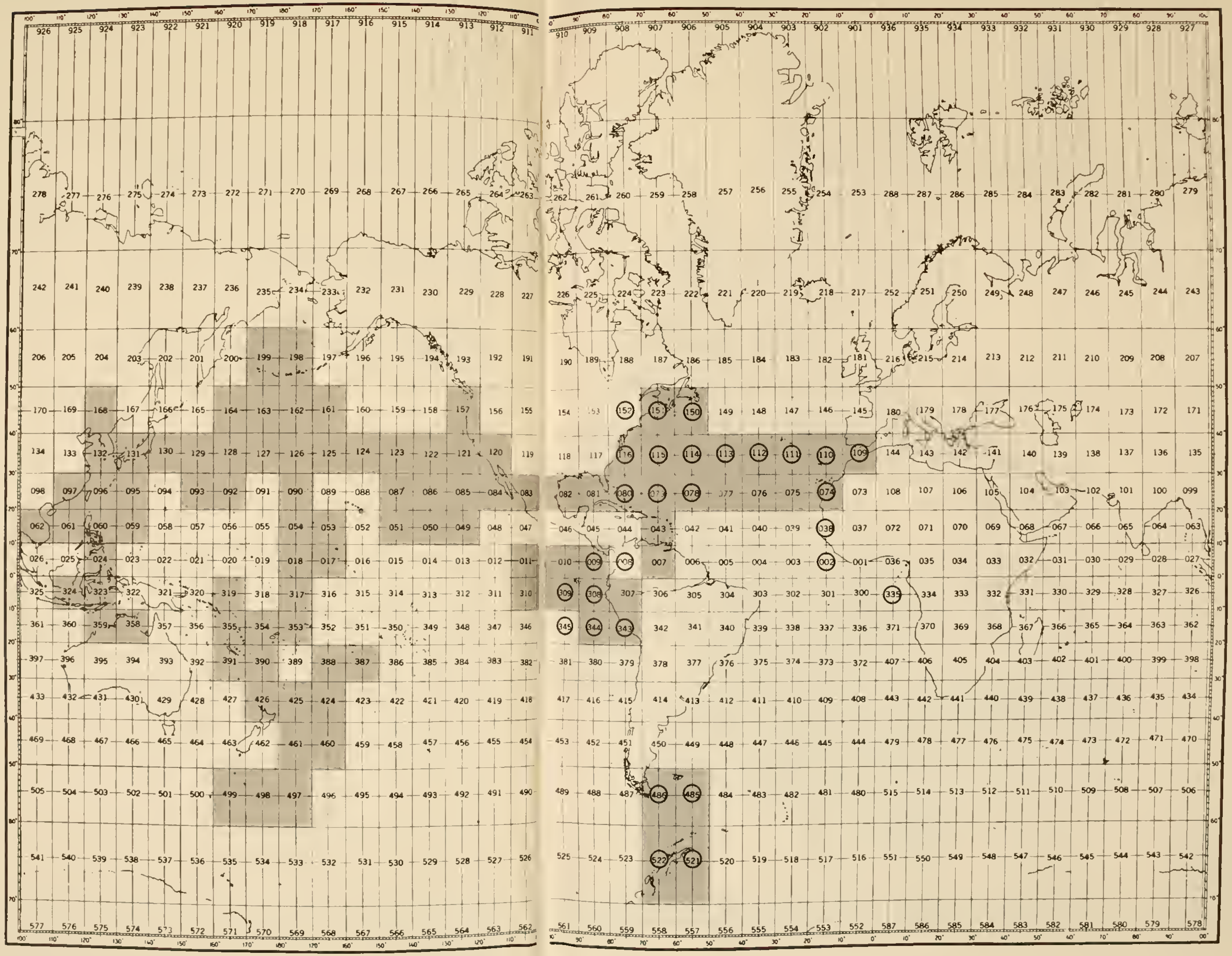
Report of the Workshop on Physical Oceanography for Post 1980 IDOE Planning. Center for Ocean Management Studies, University of Rhode Island, March 21-23, 1977.

Report of the Workshop on Biological Oceanography for Post 1980 IDOE Planning. Center for Ocean Management Studies, University of Rhode Island, April 20-22, 1977.

Minerals from Mantle to Mine, a 7 page article reprinted from *MOSAIC* May/June 1977, describes the Seabed Assessment Program's Study of East Asia Tectonics and Resources (SEATAR) project. Copies available free from the NSF/IDOE Office.

Report of the Workshop on Chemical Oceanography for Post 1980 IDOE Planning. Center for Ocean Management Studies, University of Rhode Island, June 1-3, 1977.

Report of the Workshop on Geochemical and Geophysical Oceanography for Post 1980 IDOE Planning. Center for Ocean Management Studies University of Rhode Island, June 15-17, 1977.



LEGEND

IDOE material received:

- ROSCOP forms
- Data

Chart of 10° by 10° geographic areas (Marsden Squares) within which were collected data and information reported in this publication and received by NOAA's Environmental Data Service. Note: Data and ROSCOP forms are seldom received at the same time

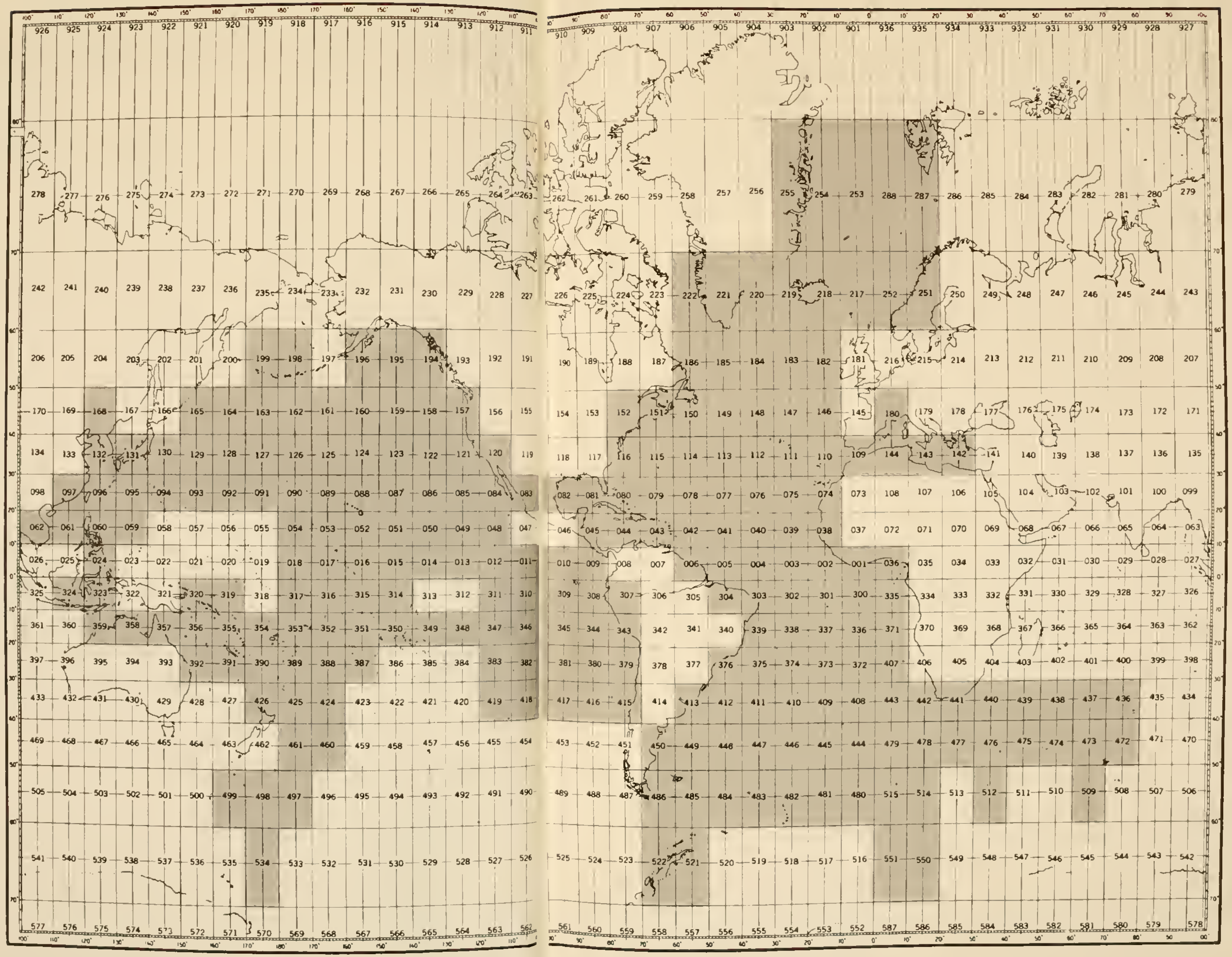


Chart of 10° by 10° geographic areas (Marsden Squares) within which were collected data received by NOAA's Environmental Data Service during the period January 1970–April 1977 (shaded squares) resulting from IDOE-sponsored research.

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Data Service
Washington, D.C. 20235

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210
THIRD CLASS MAIL

U.S.MAIL